MEDICAL ELECTRICITY

DE WATTEVILLE

57

A PRACTICAL INTRODUCTION

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WITH A

COMPENDIUM OF ELECTRICAL TREATMENT TRANSLATED FROM THE FRENCH

OF

DR. ONIMUS

BY

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ILLUSTRATED WITH ABOVE ONE HUNDRED DIAGRAMS AND WOODCUTS.

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PREFACE.

This little book is intended as a companion to the Medical battery. My only ambition in presenting it to medical students and practitioners is that it may justify its title, and be found a practical guide to electro-therapeutics, and a suitable introduction to the study of the larger treatises.

Though containing no new facts, nor original theories, a few words of explanation with regard to some points may not be unnecessary.

In the first chapter I endeavour to give a sketch of the main physical facts which have a direct bearing upon the application of electricity to the human body. Franklinism (static or frictional electricity) is not even mentioned, its use being now abandoned in electro-therapeutics. Galvanism and faradism, on the other hand, are treated of in a manner which may appear somewhat novel to the reader. "In England" says Professor Jenkin, "at the present time, it may almost be said that there are two sciences of electricity —one that is taught in ordinary text-books, and the other a sort of floating science known more or less perfectly to practical electricians . . . . The science of the schools is so dissimilar from that of the practical electrician, that a student might have mastered De la Rive's treatise, and yet feel as if listening to an unknown tongue in the company of practical men. It is also not a little curious that the science known to the practical men was, so to speak, far more scientific than the science of the text-books. These latter contain an apparently incoherent series of facts, and it is only by some considerable mental labour that after reading the long roll of disjointed experiments, the student can even approximately understand any one experiment in its entirety . . . . The difference between the electricity of schools and of the testing office has been mainly brought about by the absolute necessity of practice for definite measurement. The lecturer is content to say, under such and such circumstances, a current flows, or a resistance is increased. The practical electrician must know how much current, and how much resistance, or he knows nothing; the difference is analogous to that between qualitative and quantitative analysis. This measurement of electrical magnitudes absolutely requires the use of the word and idea potential, and of various units each with an appropriate name, in terms of which each electrical magnitude can be expressed." I have quoted these words because they explain better than I could have done it, what is, or at least what ought to be, the position of electro-physiology, and of electro-therapeutics, with regard to the electricity of the schools.

The first chapter then, is intended to convey some idea of that "practical science," and point out some of its applications to elec-

tro-therapeutics, the rational practice of which is impossible without some knowledge of the physical conditions under which we act. The physiological and other effects of the current are also briefly sketched, and some diagrams introduced, which I hope will be found useful.

In the second chapter, the reader will find a pretty full description of the various apparatus, batteries and accessories, with some practical remarks upon their relative merits and their management. The illustrations have been supplied to me by the various makers whose names they bear. I wish to tender them my best thanks for the readiness with which they have assisted me in rendering this part of my work more attractive and useful. Special mention must be made here also of Dr. Tibbit's kindness in lending me the blocks illustrating his apparatus. Some of the latest improvements will be found figured and described in the Appendix.*

In the third chapter the reader will find some practical remarks on the method of electro-diagnosis, and a succinct account of the results and views which have found an able exponent in Prof. Erb, of Heidelberg. To his courtesy I owe the permission of reproducing the valuable diagrams which have appeared in the volumes (xi and xii) he has contributed to Ziemssen's Cyclopedia. In the paragraph on reaction of degeneration, I have followed as closely as possible Prof. Erb's own description.

The chapter on electrisation is intended to give a general idea of the art of electro-therapeutics, with special directions as to the details of the various methods used.

The fifth and last chapter consists of a series of short paragraphs on the application of electricity to the various diseases in which it has proved a valuable agent of cure. This part of the book is due to the pen of Dr. Onimus, who herein summarises the results of his extensive clinical experience, based upon his well known physiological researches, which will be found partly collected in his "Traité d'Electricité Médicale." I have introduced but insignificant changes in the translation, with the exception of the attempt I have made at an electrical posology, the sole responsibility of which must therefore rest upon me.

Some figures referred to in the course of chapter V. are appended to it, illustrating the most important "motor points" of the body.

13 Old Cavendish Street, W.
June, 1878.

* Those who believe that "Electricity is life" will perhaps miss the customary descriptions of the galvanic chains and bands. My reasons for omitting them are stated at page 105. Pulvermacher's wares are, by the way, likely to be entirely cast into the shade by the latest efforts of an ingenious Frenchman, to whose inventiveness we owe the production of "an electro-magnetic shirt provided with a galvanic chain at the upper part, a mouth-piece to be inserted in the mouth, another to be fixed in the anus; and if the dress only extends to the thighs a chain may be employed for the legs with a ring at the end to be secured to the big toe"!!

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For electro-physiology consult the usual treatises of physiology, and the special works of Du Bois-Reymond, Matteucci, etc. Many of the handbooks of electro-therapeutics give some account of the physiological principles. Read also the pamphlet:

ONIMUS, Des erreurs qui ont pu être commise dans les expérience physiologiques, par l'emploi de l'électricité, pp. 50. Paris, 1877.

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A PRACTICAL INTRODUCTION

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CHAPTER I.

THE CURRENT.

GALVANISM.

ELECTRICITY, like the other forces of nature, is a form of molecular motion. Many of its phenomena can be represented under the likeness of a fluid in motion, of a current flowing; and in order to realise more vividly its manifestations, we may trace some analogies between a stream of water and a current of electricity. Such a current may be continuous, as in the case of the galvanic cell, or intermittent, and consist of a series of small currents, or "sparks," as in the case of the frictional machine, or of the induced coil; but it must be firmly remembered that the identical laws which govern the one govern also the others. Galvanism, however, offering the more typical instance, we shall confine our present remarks to the phenomena presented by the so-called constant current.

The fundamental condition of the existence of a stream of water is a difference of level between two points. If we wish to produce a flow of water from A to B we must make A higher than B. In precisely the same manner if we wish to have a flow of electricity between two points we must create a difference of level between them. This difference of electrical level is called difference of *potential.*

A galvanic element consists essentially of a vessel containing a liquid in which two plates of dissimilar metals, say zinc and copper, are immersed. To the top of each plate or electrode, is fixed a copper wire. If now these wires are successively brought into contact with an instrument called a quadrant electrometer, constructed so as to measure differences of potential, we find that such a difference exists between the two wires. Next, if we attach the wires to the terminals of a sensitive galvanometer, a description of which is given further on, immediately we notice a deflection of the needle: a current flows through the galvanometer. Further, we notice that this deflection is not temporary, but lasting a more or less considerable time. Hence, we conclude that our cell has the power not only of producing difference of potential

between two insulated points, but also of keeping up this difference when these points are connected through a conductor.

As in hydrostatics we take the level of the sea as standard level for our measurements, so in electrics we take the potential of the earth as standard with which we may compare the potential of any point of body. In fact we assume the earth to be in a state of electrical rest, as we do the sea to be at a uniform level. And as the one is a practically unlimited reservoir of water, so the other is of electricity; small additions or subtractions of fluid having no perceptible effect in altering the level in either case. The potential of a body may therefore be defined as "the excess or defect of its potential above or below that of the earth". In illustration of this conception we may adduce the thermometrical measurements of temperature. Our Zero point having been fixed, as that of the freezing point of water, we measure the temperature of bodies by refering them to the standard so chosen. As then we have levels above and below that of the sea, and temperatures above and below freezing point of water, so we have potentials above and below the earth's potential; the former are called positive potentials, the latter negative potentials. When, therefore, we say that a point is at a positive potential, we imply that if connected with the earth, electricity will flow from it to the earth, and, conversely, that if a point is at a negative potential, electricity will, under the same circumstances, flow from the earth to the point.

It will be observed that, so far, the expression of the potential, positive, or negative, of a body coincides with the statement that it is charged with "positive" or "negative" electricity. But it frequently happens that we have to compare the potentials of two points irrespective of their relation to the earth's potential; and we then speak of them as being positive and negative respectively, though both may be, absolutely speaking, positive, or both negative. But this does not constitute an exception to the general law that the flow of electricity always takes place from the higher to the lower potential; from the more positive to the less positive, if both are above, from the less negative to the more negative, if both are below the earth's potential. Exactly the same thing occurs in the case of temperatures; heat flows from the warmer to the colder point, whether both be above, or both below zero. Between two cisterns at different levels, either above or below that of the sea, the stream invariably follows the same direction. If, by means of an appropriate instrument, we test the terminals of a galvanic element, we find that the wire connected with the copper is electrified positively, and the wire connected with the zinc, negatively: hence, the names of positive and negative poles of the cell; and the direction of the current which flows in a conductor, uniting the two poles, is accordingly found to be from copper to zinc.

When the two wires are placed in mutual contact, or in contact with a conductor, we say that "the circuit is closed," implying by this expression that the current of electricity does not simply flow from positive to negative pole in the wires, etc. external to the cell, but that within the cell itself there is a current completing the

circular course. The direction of this internal current must, then, be opposed to that of the external; that is, must be from the negative to the positive pole. Hence, we see that the zinc, which carries the negative pole, is positive to the copper which carries the positive; the rule being that the metal the more readily attacked by the liquid in the cell is positive to the less attacked.

To return: A galvanic cell (and we may add a frictional machine, an induction coil, a thermo-electric couple) is an arrangement for producing a difference of potentials between two points. This difference is exhibited at the poles, the one exhibiting a certain degree of positive, the other an equal degree of negative, potential. This property of creating difference of potential depends upon an unknown cause at work within the cell to which the name of *electro-motive force* has been given. We may, roughly, compare the cell to a steam engine. As we speak of the locomotive power of the one as a fixed quantity, as long as its supply of fuel and water remains constant, so we may of the electro-motive force of the other. The electro-motive force of the cell depends upon the metals and liquids brought into contact, and remains constant as long as these are unaltered. But here the analogy ends; and it is a point of paramount importance to thoroughly grasp the idea that the electro-motive force of a cell depends upon the nature of its constituents, and upon their nature only. The size of the cell, that is, the quantity of the metals and liquids used in its manufacture, leaves its electro-motive force absolutely unaltered. When, as in medical batteries, a number of cells are united in series, the difference of potentials at their two terminal poles will be equal to the sum of the electro-motive forces in the cells. For all practical purposes we can thus take electro-motive force and difference of potential as synonymous; the latter may be considered as the external manifestation of the former.

To sum up and illustrate this point by means of a hydrostatical example: The two poles of a battery are comparable to two cisterns placed at different levels: Connect these by means of a pipe, and a flow will take place from the higher into the lower cistern. The electro-motive force of the battery corresponds to the pressure, which urges the water from the higher into the lower cistern, due to the difference of level. This leads us to a further consideration. The flow of water is the stronger, first, the greater the difference of level between the two cisterns; second, the larger the diameter of the pipe.* Suppose now the two poles of a cell to be connected by means of a copper wire, exactly the same law will apply: the strength of the current, that is the quantity of electricity flowing in a given time, is proportional to the electro-motive force in the cell,† and to the diameter of the wire.

But this is not all. If instead of being of copper, the wire used is of German silver, we find that the current is very much weaker, though the diameter of the wires be exactly the same. Under the

* Neglecting the effects of friction.

† Assuming of course the internal resistance to be negligible.

same circumstances, different bodies give different results, and we are led to the conclusion that every substance does not conduct an electrical current equally well; in other words, that besides the diameter of a conductor, its *specific resistance* must be taken into account.

In order to make this clearer, we may suppose our cisterns to be connected through a number of pipes of the same diameter, but packed with bits of sponge, or pumice, some very loosely, others again very tightly. It is evident that the amount of water transmitted by each will be inversely proportional to the degree of tightness of the packing, that is, to the resistance offered in each to the flow. Exactly the same obtains for bodies considered as electrical conductors: some transmit the current freely, some with greater difficulty, some very sparingly indeed. So besides the diameter of a wire, for instance, the metal it is made of, must be taken into account, and its specific resistance allowed for. Metals are the best conductors. Even the worse conducting ones among them, such as mercury or bismuth conduct far better than non metallic bodies. Carbon conducts fairly well. Acids and solutions of salts have much less resistance than pure water. Bodies such as resins, india-rubber, silk, glass, dry air conduct so badly as to deserve the name of "Insulators." The human body is a bad conductor—the dry epidermis almost acts as an insulator.

Let us now put the two ideas of electro-motive force and resistance together in the shape of a formula. The current of electricity will be directly proportional to the electro-motive force, and indirectly proportional to the resistance in the circuit. Or mathematically, $C = \frac{E}{R}$. This is *Ohm's law*, the foundation-stone of electrical science.

Let us consider R a little more closely. It represents the resistance in the whole circuit. In travelling from the positive to the negative pole of a cell, the current encounters the resistance of the wire, human body, etc., which are included in that part of the circuit. This we call the external resistance. But inside the cell what takes place? The current, in order to complete the circuit, must flow from the positive to the negative metal, and there also it encounters a resistance, viz., that of the liquids and diaphragms interposed.

This we call the internal resistance, and our equation $C = \frac{E}{R}$ becomes $C = \frac{E}{R' + R''}$ where R' is the resistance in the battery, and R'' that outside. We shall see that R' is often a most important element in electrical matters, and one which is often wholly lost sight of.

Before proceeding any further we must pause to consider what actual quantities the letters C, E, R represent in the equation just given.

It is a great defect in the old-fashioned text-books of electricity, and with them in electro-therapeutical treatises, that they convey no definite idea by the enunciation of Ohm's law on account of

their leaving the terms electro-motive force, etc., in the state of mere abstractions, without embodiment into actual magnitudes.—The unit of electro-motive force is the *volt:* we speak of a battery of so many volts as we would of an engine of so many horse power. In both cases these expressions designate the capacity of the machine to overcome resistance. The most convenient standard of electro-motive force is the Daniell's element, which has an electro-motive force of 1·08 volt. The bichromate of potash cell is nearly twice as powerful, having a force of 2·02 volts. We can consider the *ohm* as unit of resistance in very much the same light as the metre as unit of length. To the practical electrician, the ohm is simply a standard coil of copper wire 1 m.m. in diameter, and 48·5 m. (nearly) in length; or else a column of mercury 1 sq. m.m. in area, 1·05 metre in height. We need not trouble ourselves how nor why these units were so obtained and chosen, but have simply to adopt them, as we do the metrical system. A little practice only is required to realise the facts conveyed by these terms; and we shall be amply repaid for our trouble by the clearer conception of electrical phenomena, and the possibility of recording our observations in accurate and universally understood language. It is mere waste of time to speak in vague and often erroneous terms of the "high tension" of batteries of the "infinite resistance" of the human body. And what a vast amount of useless controversy has been expended over matters which could have been explained in an instant by reference to the facts of the case! Thus for instance, it being found that the current from 35 disulphate of mercury cells vesicates the skin in a very short time, whilst the current from 45 Siemens' elements can be borne without discomfort for a long time, it is concluded that the current from the latter has qualities which especially suit them for therapeutical purposes—whereas the facts are these. The 35 mercury cells have an electro-motive force of about 52 volts, and an internal resistance of 100 ohms. The 45 Siemens' have 48 volts, E.M.F., and 1500 ohms R'.—What happens then is this: in the first case the current flowing through the human body (whose resistance is, say, 2500 ohms).

$\frac{52}{100 + 2500} = \cdot 02$. In the second $\frac{48}{1500 + 2500} = \cdot 012$. In other words the current in the first instance is nearly twice as strong as in the second. No wonder then that the effects are different.

We are thus brought to consider a little more closely the idea expressed by the words *strength of the current.** Indeed this is the turning point of the whole subject.

A current of a given strength, be it a current of water, or electricity, or of any other "fluid" performs a certain amount of work, no more, no less. The current of water causes the wheel to revolve so many times in a minute; the current of electricity deflects a needle so many degrees, decomposes so many grammes of water,

* Current strength is the term now used instead of "intensity of current," a useless and misleading expression imitated from the French.

salts, or animal tissue, heats a wire to such a temperature, magnetises a piece of iron to such an intensity, exerts (within physiological limits) such an action upon the organism. With every change in the strength of the current, its mechanical, physical, chemical or physiological effects will display a proportional change in their intensity. It matters not what be the source of the current: it may be chemical work as in the case of the voltaic pile, or mechanical, as in Gramme's machine; its effects are the same, its strength being the same. It is idle, therefore, to attempt to show the superiority of this or that kind of element, except on the ground of convenience or constancy. Electro-motive force is one, and the resistances in circuit remaining unaltered, the current is one, and the work done remains the same. To deny this is to ignore the doctrine of the correlation of forces.

From the enunciation of Ohm's law $C = \frac{E}{R}$ we see that the unit of current-strength is determined by the strength of a current impelled by an E.M.F. of one volt through a R of one ohm, for $\frac{1}{1} = 1$. But what constitutes the strength of a current, that is its capacity for work? It is the quantity of fluid conveyed in a unit of time through any sectional (equi-potential) area of the channel. A current of unit strength, then, is a current that conveys a unit of quantity in a unit of time. It is a current which conveys, in the case of water, one gallon in the second; in that of electricity, one *veber* in the second.

The veber is the unit of electrical quantity, and from the definition, is that quantity produced in one second by one volt, through one ohm. This quantity, again, is that necessary to set free 0·1146 cubic centimetres of hydrogen from the electrolysis of water (at oC., and 760 m.m. pressure).*

It is clear then that when we speak of currents of ·01, ·1, 1, 1·5, &c., we designate currents conveying ·01, ·1, etc. veber in the second; or conversely conveying 1 veber in 100, 10, 1, ·666 second respectively.

Practically the current corresponding to the unit strength is comparatively rarely used. In most cases, among which are medical applications, the currents used are much weaker. Hence a proposition has lately been made which, I think, ought to be adopted, viz., of adopting the thousandth of a veber as a working unit, and call it milliveber. As it happens it exactly suits medical purposes, for a current of 1mv. is that given by about 3 Daniells through the average resistance ot the human body. It is obviously simpler to speak of currents of 1, 5, 10, 20 millivebers, than of ·001, ·005, ·01, ·02, veber; these are the limits of medical currents. Hence, expressed in absolute measurement, "weak" currents in electro-therapeutics are currents of 1—5, "medium" from 5—10, "strong" from 10—15, "very strong" from 15—20 millivebers.

* The unit of capacity, or farad, need only be mentioned here, it is the same as the veber, and the two are often included under the same name.

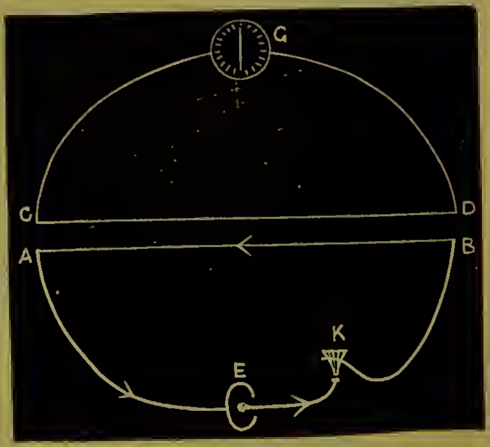
FARADISM.

Induction is the name given to a phenomenon exhibited by a wire or other conductor, in the neighbourhood of which a curren. or a magnet is placed. As long as no change occurs in the distance and strength of the latter nothing occurs in the wire; but as soon as any such change is set up, and as long as it lasts, electromotive force is generated in the wire. In other words, whenever a current (or magnet) is (suddenly or gradually) made or broken near a wire (that is, whenever it is brought from an infinite distance into its neighbourhood, or thence removed to an infinite distance), and whenever any variation of strength occurs in the current (or magnet) while at rest, a certain amount of electromotive force is induced in the wire.

This amount is absolutely definite in each case,. depending upon the length of the wire influenced and the variation in the current. Suppose that in one case a current of 1 unit be made suddenly, that is in a very short time, say $\frac{1}{100}$th of a second, in the wire AB; and in another case be gradually, say in one second, made, that is increased from 0 to 1, we shall have in both instances a total electro-motive force X generated in CD. But it is evident that at any instant of its existence the second current is 100 times weaker than the first, and though the same total quantity of electricity is conveyed in the two cases, the effects in the first will be much greater owing to the concentration of that quantity in a very short time.

Ohm's law governs induced currents, as we said, just as it does galvanic. As in dealing with a battery we have to consider its internal resistance, so in dealing with the induction coil we have to keep in mind the resistance of the wire itself. The resistance of wires vary directly with their length, indirectly with their diameter. The primary coil of faradising apparatus, for instance, being always made of a short thick wire has a much less resistance than the secondary coil which usually consists of a much longer and thinner wire. If we connect the wire CD with a galvanometer, and changes of current occur in CD, we shall find that the needle is not always deflected in the same direction. When the current from B to A is made, increased, or brought near, the current induced in CD is observed to flow in the opposite direction, viz., from C to D. The reverse takes place when the current BA is broken, diminished, or removed. If then by means of a key K, we alternately make and break the current, the needle

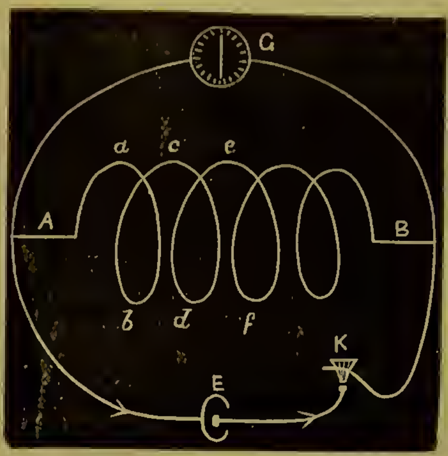
FIG. 1.



will alternately swing to the right and to the left as the case may be.

Now suppose the wire AB instead of straight be in the shape of a coil. It is evident that the consecutive turns may be considered as constituting a series of parallel wires (*a*, *b*, *c*, parallel to *c*, *d*, *e*, etc.). In fact, we find that every variation of the current in its passage through each turn from B to A does induce electromotive force in the contiguous turns. An induced current is thus generated in AB which obeys the same laws as that arising in an independent wire; viz., is opposed in direction to the primitive battery current, when the latter is made or increased; similar in direction when the latter is broken or diminished. This current is known as the primary or extra-current.

Fig. 2.



Let us suppose, as in the diagram, that AB is connected with the two poles of a battery E, and that the current can be made and broken at will by means of a key, K. Connect AB with a galvanometer G. We now find that on breaking the current from the battery, a strong induced current is generated which causes the needle to be strongly deflected. But on making the current again no such deviation is observed; the induced current being opposed in direction to the battery current acts as a momentary resistance to it. The battery current is weakened and retarded in the process.

Suppose now that the second wire CD be also made to assume the shape of a coil, so as to surround the coil AB. It is evident that each coil turn in CD may be considered as parallel to each turn in AB. The total inductive influence of the coil AB upon the coil CD will be proportional to the total number of turns in the first multiplied by the total number in the second. By increasing the number of turns, we therefore increase the amount of electro-motive force generated. Experiments have shewn that this amount is independent from either the material or the thickness of the wire. These circumstances influence only the resistance of the coil.

Fig. 3.

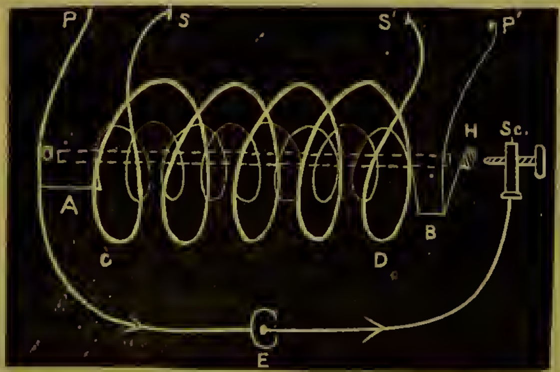
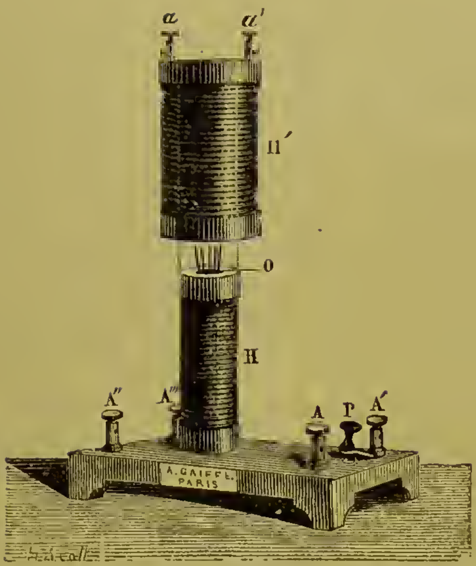


FIG. 4.



Apparatus for demonstrating the phenomena of induction: H primary coil, the two extremities of which are connected with AA' and A'' A'''. P is a spring which when pressed down closes the circuit through AA' and the coil. O is an empty space in the coil for the introduction of soft iron rods, or a magnet. H' secondary coil, the extremities of which are connected with the binding screws *aa'*.

The wires from the battery are attached to H A' and the circuit alternately made and broken by means of the key P. The extra-current is obtained at A'' A''', and the secondary at a a'.

The ordinary medical induction apparatus consists of:

1. The battery E, composed of one or two elements, one of the poles of which is connected with the screw of the interruptor, Sc., the other with one end of the primary coil, A.

2. The automatic interruptor consists of the spring hammer, H, which when at rest is in contact with the screw, Sc, just mentioned. Its free extremity impinges upon the iron core of the primary coil, and its fixed base is connected with the second end of the primary coil B.

3. The primary coil, AB, is made of a short thick wire. Its extremities are fixed to the battery and hammer respectively, as just mentioned.

4. A core, O, composed of a bundle of iron rods, inside the primary coil.

5. The secondary coil, CD, made of a long thin wire. It is entirely independent from the rest of the apparatus, and its two extremities are connected with two binding screws, s, s', to which the rheophores are attached.

6. Two wires branching from the extremities of the primary coil, AB, and terminating at two other binding screws, P, P', for the rheophores. These wires convey the extra current.

7. All apparatus are fitted with contrivances for graduating the current strength.

The extra current is modified by means of a draw-tube made to enclose more or less of the primary coil. When the latter is completely enclosed the current is considerably diminished.

The secondary coil is likewise made to include a desired length of the primary. The current strength increases with the length so included.

In some instruments the wires are tapped at different lengths which may be taken successively by means of a dial collector: the current is proportional to the length so used. Or again, a water rheostat is included in the circuit: this is a very convenient mode of graduating the strength of faradic currents.

The action of such an apparatus is as follows: The moment the current begins to flow in the primary coil, the iron becomes magnetic, the hammer is attracted, and the contact between the screw and hammer broken. The current ceases to flow. Immediately the iron is demagnetized, the attraction ceases and the hammer flies back, in virtue of the elasticity of the spring, into contact with the screw. Once more the current begins to flow and the same succession of phenomena is repeated. It is evident that the rapidity of these makes and breaks depends upon the time taken by the hammer to swing to and fro, that is upon the freedom of play of the spring. Provision is made in most apparatus to modify this by screw arrangements, etc., but usually this is quite insufficient. Slow interruptions have then to be made by moving the hammer with the finger. A Duchenne's pedal is a most useful addition to the faradic apparatus.

At each make of the battery current, then, we have two induced currents, one in each coil, opposed to it in direction; at each break we also have two induced currents, flowing in the same direction.

We have seen that the make primary current simply retards the developement of the primitive (or battery) current, acting as a temporary resistance in the primary coil. The result is that the time taken by the battery current to attain its maximum strength is prolonged; hence, the generation of electro-motive force in the seconday coil is protracted, and as a consequence the make induced current is weakened in proportion to its longer duration.

The break primary current (or extra-) current, and the break secondary current are much more rapidly induced, the whole electro-motive force generated coming into play instantaneously, so to speak; hence they alone have an appreciable physiological effect when a resistance, such as the human body, is included in the circuit. The extra (or primary break) current manifests itself as the spark which flies between the hammer and screw. It is due to the passage of the current through the air as the hammer recedes from the screw. Hence it is most vivid when the extra-circuit is not closed, and becomes fainter as the resistance in the extra-circui becomes smaller.

Hitherto we have said nothing of the influence of the core of soft iron in the primary coil upon the induced currents. As previously mentioned, the influence of magnets made or unmade in presence

of wires brought near or removed from them is precisely the same as that of galvanic currents. The magnetisation and demagnetisation, therefore, of the soft iron increases the amount of electromotive force generated in the coils by the make and break of the battery current; for as stated, this magnetisation and demagnetisation occur synchronously with make and break.

The physiological distinction of poles has to be observed in faradic as well as in galvanic currents: (1). This is obviously the case with the primary coil where the make current is neutralised by the battery current. (2). The secondary make current, unless produced by a very powerful coil, has practically no influence whatever when circulating through the high resistance of the body. Currents produced in the same coils vary in their physiological action according to, (1), their absolute strength (depending upon the strength of the battery current used, and resistance in the circuit, (2), the rapidity of the interruptions (depending upon the arrangement of the hammer).

The difference between the primary and secondary current depends upon the fact that the former arise in a short thick wire, the latter in a long thin one. Ohm's law explains the phenomena observed. Suppose the electro-motive force generated in the primary coil, the resistance of which is, say, 1 ohm, to be equal to 5 volts; that in the secondary (resistance 1000 ohms) to be 100 volts. If we send these two currents successively through a galvanometer of say 4 ohms resistance, the deflections of the needle indicate current strengths,

In the first case: $\dfrac{5}{1 + 4} = 1.$

In the second case: $\dfrac{100}{1004} = {\cdot}1$ nearly.

If the resistance of the galvanometer be 50 ohms, the two currents will be almost equal, for $\dfrac{5}{50 + 1}$ and $\dfrac{100}{1000 + 50} = {\cdot}1$ nearly.

If again the resistance in the circuit be 2000, as for instance that of a portion of the human body, the strength of the current in the first case will be only ·0025, in the second ·033, that is in the proportion of 1 to 13. These numbers are only typical of course, but serve to illustrate the principle just stated.

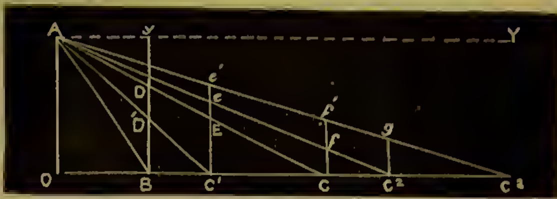
The difference between two such currents is expressed by saying that they are of "low and high tension" respectively.

ON THE GRAPHICAL METHOD OF REPRESENTING ELECTRICAL PHENOMENA.*

It may be found useful to represent the relations between electromotive force, resistance, and current strength by the following graphical method. Let the length OC represent the total resistance

* See Prof. Carey Foster's paper in *Philosophical Magazine*, May, 1875.

FIG. 5.



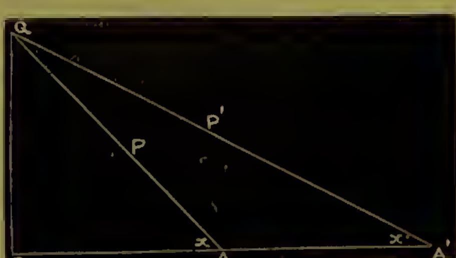
of the circuit of which OB is equal to the (internal) resistance of the battery, and BC the (external) resistance of the conductor interposed. Draw OA at right angles to OC representing the electro-motive force of the battery. Join AC. The current strength will be represented by the *slope* of AC, that is, by the tangent of the angle ACO, which we know is the geometrical expression for the proportion $\frac{AO}{OC}$ (that is $\frac{E}{R}$).

Let OA be 15 millimetres long, representing the electro-motive force of 8· Bunsen's cells (15 volts), and OB be 10 m.m. long, representing the internal resistance of the battery (10 ohms). And let our external resistance of twenty ohms be represented by as many m.m. in BC.—Join AB. The strongest current we can obtain with our battery, is when the poles are directly connected, and then our current = tan ABO. If OC′ be made equal to AO, the angle AC′O has 45 degrees, and our current is equal to tan 45° = 1 $\left(\frac{15 \text{ volts}}{15 \text{ ohms}}\right)$. With every increase of our external resistance, CC_2, CC_3, the slope of AC_2 AC_3 goes on diminishing until it vanishes altogether; we then have AY parallel to AC prolonged to infinity. An infinite resistance being interposed, no electricity can flow, of course; the circuit is broken.

Now draw BD parallel to AO. The length of BD represents the difference of potential between the poles of the battery when the current flows through the external resistance BC, that is to say, the "tension" of the battery, or again, the electro-motive force which is effective in maintaining the current through BC. With every diminution of BC, (BC′) BD will diminish (BD′); until BD vanishes altogether when there is no external resistance, the poles being in contact. With every increase of BC, (BC_2, BC_3) BD will increase until it becomes B*y* = AO when contact is broken. As a general rule the potential of a point in a circuit is equal to the ordinate of that point.

Let us apply these principles to a concrete example: To find the electro-motive force and internal resistance of a given battery, with a given tangent galvanometer, and a given external resistance. First, connect the poles of the battery to the terminals of the galvanometer; let the deviation of the needle = X. Next introduce into the circuit the given resistance R, and let the deflection = X′. Take a straight line OA, and make the angle OAP = X. Produce the line OA to A, and

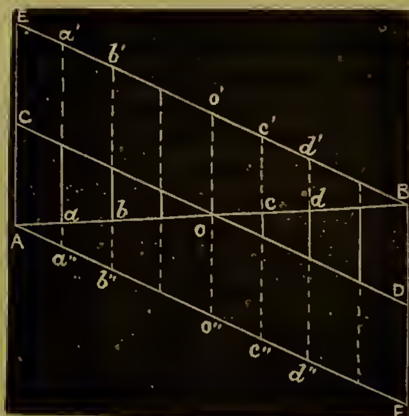
FIG. 6.



let AA′ represent R; make the angle OA′P′ = X′. Let AP, and A′P′ meet, as they must, at a point Q. From Q let fall QO perpendicular to AO produced if necessary. Then OA = internal resistance of the battery + known resistance of the galvanometer, and OQ = electro-motive force of the battery, in terms of that electro-motive force taken as unit, which if it acted in a circuit of unit resistance, would generate a current capable of causing a deviation 45° upon the galvanometer employed. That is, if every inch, millimetre, or any other unit of length adopted for OA′ denotes one ohm, the length of OQ expressed in terms of the same unit will denote the electro-motive force of the battery in volts; for $\frac{1 \text{ volt}}{1 \text{ ohm}} = 1$ and tan 1 = angle 45°.

Let A and B be two points in a circuit, the two poles of a battery for instance, and the length of AB represent the resistance of the conductor interposed. Let AC be made equal to the electro-motive force acting at A (*i.e.*, the potential of A) and BD that at B, the potentials of these two points being positive and negative respectively. Then the slope of CD, that is the tangent of the angle AOC represents the strength of the current; and the potentials of any points *abcd* along AB are equal to the ordinates of these points (drawn in the diagram as full lines betweeen AB and CD. The point O, which is at zero potential, occurs at the middle point of AB.

FIG. 7.



By means of an "earth wire," that is of a wire connected with the earth (usually through the intermediacy of a gas or water pipe), any other point in the circuit may be brought to zero potential. Suppose we so connect the negative pole B of the battery: it is then at zero. But the electro-motive force of the battery remains unaltered, and the difference of potential between A and B, still equal to AC + BD, that is equal to AE. The current remains unaltered for ABE = AOC; but there occurs a redistribution of potentials along the whole of AB; the potential of every point A, *a*, *b*, O, *c*, *d*, B, being raised by the value of BD. Hence the ordinate AE, *aa*′, *bb*′, O*o*′, etc., represent these potentials which are all positive. The opposite occurs if the point A is connected to earth. The potentials *aa*″ *bb*″ O*o*″ are now all negative. Any point intermediate between A and B being so connected, a corresponding redistribution of potentials occurs: in order to represent the state of things when the point *a*, for instance, is connected to earth, we have simply to draw a line through *a* parallel to CD; and the potentials of A, *b*, *c*, *d*, B would be represented by the ordinates of these points.

MEASUREMENT OF ELECTRO-MOTIVE FORCE.

Electro-motive force may be measured statically by observing the potential (that is, the "tension" of the older authors) of the point at which it acts. For this purpose one of Sir W. Thomson's electrometers is used. "Those instruments are of two very distinct forms: the "portable" and the "quadrant" electrometer. The action of each depends on measurement of the attraction between two planes, one of which is electrified to a constant potential, and the other brought to that which is to be measured. In both forms the potential of the electrified plane is kept tolerably constant by being connected with a Leyden jar of considerable capacity, formed by the case of the instrument. . . . . The ordinary portable instrument will measure a difference of potential, not less than that of about 1 Daniell's cell. The quadrant electrometer is much more sensitive, and will indicate a difference of tension of $\frac{1}{100}$ that of a Daniell's cell." (For a fuller account of these beautiful instruments, the reader is referred to Prof. Jenkin's *Text-Book*, pp. 203 ff).

The electro-motive force of a cell or battery may be estimated by comparison with that of some known constant element, taken as unit. The Daniell is usually so chosen. A circuit is formed containing a rheostat, a galvanometer and the known electro-motive force E. A convenient deflection having been obtained by intercalation of the necessary resistance, the second electro-motive force E' is substituted for the first, and the current brought to the same amount by means of the rheostat. Let R be the total resistance in the first case, and R' that in the second; then we have

$$\frac{E}{E'} = \frac{R}{R'}$$

By using a sensitive galvanometer and a high rheostat resistance, the resistance of the battery and galvanometer may be neglected. Other methods exist, but need not be explained here.

In order to measure in absolute units the electro-motive force of a given cell or battery we may make two measurements on a tangent galvanometer with different rheostat resistances. Suppose a cell gives with R and R' ohms, currents of C and C' vebers respectively; then its electromotive force $E = CC' \frac{R'-R}{C-C'}$.

The same result is obtained more simply by a single measurement with a known resistance in circuit, upon a galvonometer divided into millivebers. Or, again, a galvanometer may be used, whose dial has been experimentally divided, so as to indicate directly the E.M.F. in volts, provided that the internal resistance of the elements measured be negligible.

MEASUREMENT OF RESISTANCES.

We have seen that the total resistance is made up of the internal R, *i.e.* the resistance of the battery, and the external, R', *i.e.* in electro-therapeutics the resistance of the human body and electrodes.

In order to estimate the internal resistance of a battery, all we

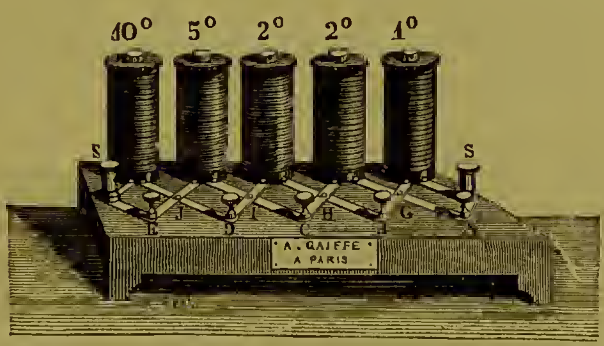
have to do is simply to connect its poles with the terminals of a tangent, or any other suitable galvanometer (whose resistance we assume to be negligible), and note the deflection. This gives us the current strength C, which as we know is the quotient of E by R. We now introduce into the circuit a rheostat, and put in resistances until the needle shows that C is diminished by half. It is obvious then that the additional external resistance must be equal to the internal, for since $\frac{E}{R} = 2 \frac{E}{R + R'}$ $R = R'$.

If it is the resistance of a part of the human body that we wish to determine, we first note the deflection given when that part is in the circuit. We then replace it by the rheostat, and so arrange our artificial resistance, that the deflection obtained is the same as before: this resistance must be the same as that of the body, for $C = \frac{E}{R + R'}$ in both cases, hence R′ must be the same.

A Rheostat (using this term generically) is an instrument so constructed as to allow the interposition of definite resistances in a circuit. Of the numerous forms that have been devised, only two or three are of importance to the medical electrician.

Wire Rheostats, otherwise called resistance coils, consist of coils

FIG. 8.



Gaiffe's resistance coils, measured resistances are introduced iuto the circuit by placing into it the coils marked 1, 2, 5, 10. S, S, binding screws for theophores. A, B, C etc. handles for working the instrument.

of fine German silver wire. Each coil a definite resistance of so many ohms, depending upon the length and fineness of the wire; and by a simple mechanism can be brought into the circuit. It is then easy with such an instrument to introduce any required resistance in a circuit.

Liquid Rheostats consist of a column of water, either pure or containing a salt, such as sulphate of copper, in solution. The instrument is usually made of a piece of glass tubing capped at both ends with a metallic disk. To these disks are attached the rheo-

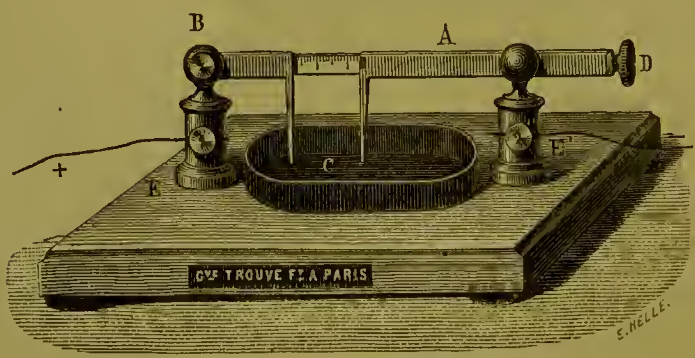
FIG. 9.

Gaiffe's liquid rheostat.

phores; and through one of them a metallic rod works like a piston. The rod is long enough to touch the opposite disk when fully pushed in. The current, then, encounters no sensible resistance; but as the rod is withdrawn and a layer of liquid is interposed, a resistance is created which will be proportional to the thickness of that layer and to the specific resistance of the liquid employed, and inversely to the diameter of the tube.

A rough but useful rheostat can be extemporised out of a piece of glass tubing, two corks, and some stout copper wire. The tube, filled with the liquid is corked up at both ends. Through one of the corks a short piece of wire is inserted which just dips into the liquid; whilst through the other a longer piece acts as a piston. The rheophores are attached to the wires. When very high resistances are required, and the tube must be short, pure water may be used. (fig. 9.) Usually, however, a solution of sulphate of copper is preferable as obviating the polarisation. A column of saturated solution 1 metre high, ·5 square centimetre area, gives a resistance of about 6000 ohms. The more dilute the solution the greater its specific resistance; hence the shorter the tube required.

FIG. 10.



Trouvé's liquid rheostat. The rod A is regulated by means of the brass head D. The length of the column of liquid C, interposed in the circuit, is read off the measured scale. The current enters at E, passes through the pillars B, through the metallic pieces and points, and the liquid; making its exit at E'. This instrument is, of course, intended not for measuring accurately, but only for interposing approximate resistances.

Liquid rheostats should be accompanied with a scale corrected from simultaneous readings on a set of resistance coils. Even then, however, they are not reliable for accurate measurements, though amply so when used for introducing approximate resistances in a current for medical purposes.

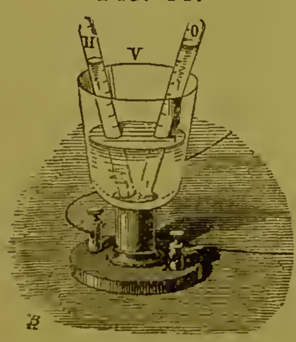
A third kind of rheostat, which possibly may yet be found the most suitable for medical practice, though much is yet required to bring it to perfection, is that in which *powdered graphite or metallic oxide* is used. These substances may be simply spread out in thin lines on a vulcanite board, when a resistance is to be extemporised, or reduced to a solid compound by admixture with various non-conducting bodies, such as gums, in such proportions as to yield hard cylinders of the requisite specific resistance. Attempts are being made in that direction: if successful, we may hope to be placed in possession of a cheap and useful instrument.

MEASUREMENT OF CURRENT STRENGTH.

We have seen that the strength of the current determines the amount of work, chemical, mechanical, etc. which it can perform. It is evident that the converse of this proposition is true, and that the work performed will always indicate the strength of the current flowing. Instruments for measuring currents are based upon this principle; the two kinds chiefly used are the voltameter and the galvanometer. The *voltameter* is an arrangement in which the chemical action of the current is made use of to indicate its strength. Electricity in passing through water decomposes it into hydrogen and oxygen. If then, the amount of gas given off by a current in a certain time be collected and measured, we shall be able to determine the strength of this current. The unit current of one veber (1 volt through 1 ohm) gives off nearly ·115 c.c. of hydrogen in a second, that is about 6·9 c.c. in one minute.

Voltameters are made for collecting the two gases, either separately or together. They consist mainly in a vessel filled with acidulated water into which project two wires or plates of platinum. The products of electrolysis are collected in glass tubes, standing over these electrodes; the hydrogen is given off at the negative, the oxygen at the positive electrode.

FIG. 11.



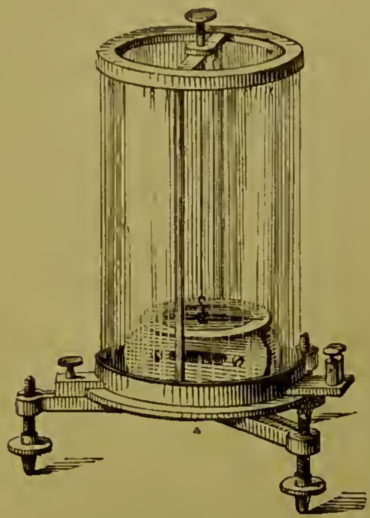
Gaiffe's voltameter for collecting the gasses separately, H and O.

FIG. 12.

Gaiffe's pocket voltameter.

For several reasons the voltameter is not suitable to medical practice. The *galvanometer*, on the other hand, will be found exceedingly convenient and useful. Electrical currents have the property of deflecting a magnetic needle in the neighbourhood of which they flow, and equal deflections on the same galvanometer always indicate currents of the same strength. But it must be carefully kept in mind 1°, that the angle of deflection is not *proportional* to the current, and 2°, that it differs for the same current strength from galvonometer to galvanometer, depending upon the length (*i.e.*, number of turns) and the position of the coil.

Fig. 13.

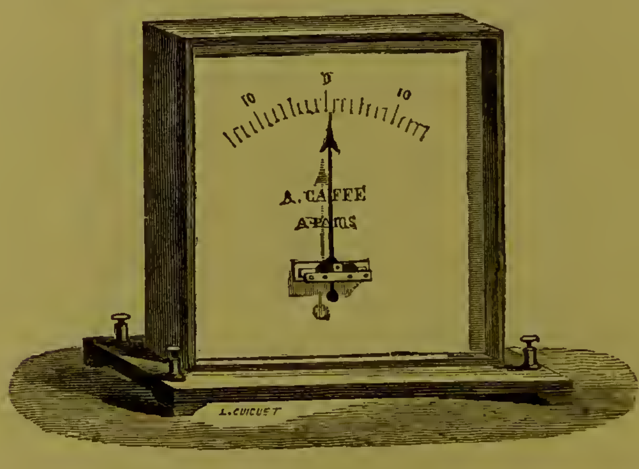


Gaiffe's Du Bois Reymond galvanometer with 10 or 25,000 turns of fine wire for measuring physiological currents.

The galvanometer may be briefly described as an instrument consisting of a magnet freely suspended or pivoted in the centre of a graduated disk, so as to be easily deflected by the passage of a current in a coil of insulated wire, properly disposed in its neighbourhood.

Sometimes the needle is placed within the coil as in fig. 13, and is rigidly connected with a pointer, both being suspended by means of a fine silk thread. The pointer may consist of another magnet forming an "astatic" system of much greater sensibility. A fuller description of these and the following instruments would be out of place here; the reader is referred to Prof. Jenkin's *Text-book* for further details. A vertical weighted needle may be used as in

Fig. 14.

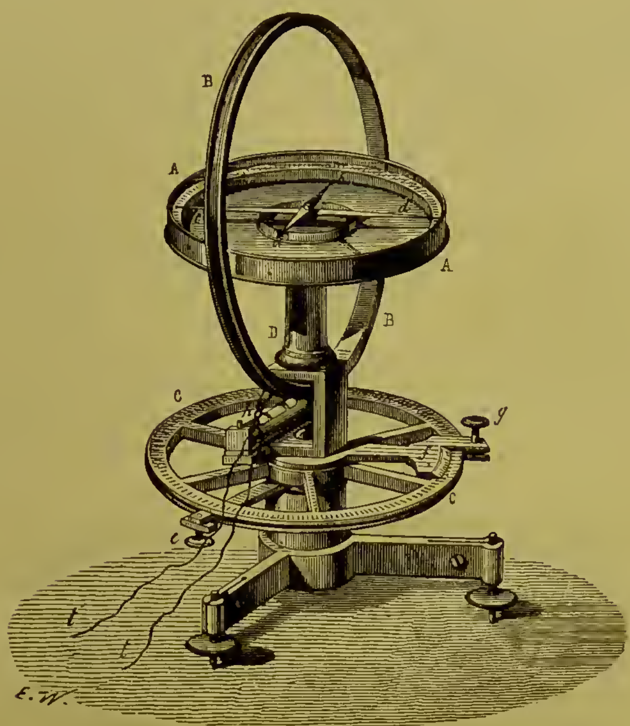


Vertical galvanometer.

fig. 14. This is a convenient arrangement, but subject to variations which render it less accurate.

The sine galvanometer is an instrument so constructed that the sines of the angles of deflection produced upon it by currents of different strengths, are proportional to these strengths. (fig. 15).

FIG. 15.

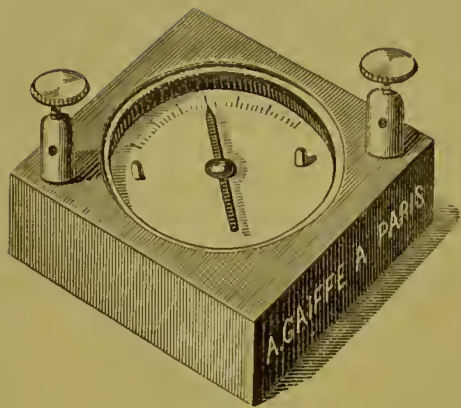


Gaiffe's sine galvanometer.—A magnetic needle *a*, *b*, carrying a long pointer *c*, *d*, revolves in the centre of the dial A, A, divided into 360 degrees. B, B, is a circular frame supporting the coil of the wire *t*, *t'*. A spirit level *h*, serves to secure the horizontality of the instrument.

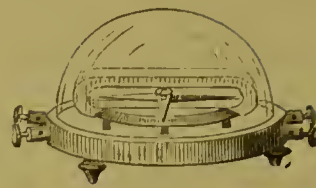
As far as this the instrument is mainly the same as the tangent galvanometer, with the exception that in the latter, the needle must be much smaller. The remaining parts consisting of a gradual circle C, and an index *f*, serve to determine the total angle of deflection, the sine of which is proportional to the strength of the current.

With the tangent galvanometer it is the tangents of the angles which are so proportional. These instruments, again, do not give the absolute current strength; that is, the results given by each are in terms of itself. In order then to obtain measurements in absolute units, the sine or tangent must be multiplied by a constant, called the reduction factor of the instrument. For medical purposes their size alone renders them unpracticable.

A Fig. 16. B



Galvanoscope for medical batteries.



Gaiffe's medical galvanometer with two wires, a short thick one for measuring "low tension," and a long fine one, for "high tension" currents. The dial is divided into arbitrary divisions (360 degrees), or into absolute units (10,000ths of B.A. units).

The ordinary galvanometer, or rather galvanoscope, is a much simpler instrument, but also one of very little use indeed, except to indicate whether any current is passing or not, and whether the battery is constant. As it obeys no law in the deflections it gives, no calculation can transform readings obtained by it into even proportional measurements. It consists simply of a coil of wire influencing a magnetic needle, revolving on a dial divided into 360 degrees. (fig. 16B).

Fig. 17.

Of late years a great improvement has been achieved in having the dial of the galvanoscope subdivided, not into degrees, but into divisions, indicating at once the strength of the current in absolute units. This plan has been adopted by Gaiffe, of Paris; and is patented in this country by Sprague, of Birmingham. By this

method we are put into possession of a most simple and accurate method of estimating our current strengths. The instrument is divided into ten thousandths of vebers (that is in tenths of millivebers). This is done experimentally by noting the deflection given by the needle with currents of known strength. An idea of the peculiarities of the absolute galvanometer, contrasted with the galvanoscope, will be obtained by a glance at the diagram. It represents the dial of an instrument divided in its upper half into degrees, in its lower half into tenths of millivebers. The principle that the angle of deflection does not increase proportionally to the current strength, is illustrated by the fact, that whilst for instance a current of 3 mv. deflects the needle to about 45°, a current of 15 mv. is required to deflect it to 70°. Hitherto the only medical galvanometer made in this country upon this principle, is not adapted to general use. It is rather bulky, and does not revolve, which limits its application to stable batteries. It is to be hoped that Mr. Sprague will soon provide us with a more handy instrument.

An ordinary galvanoscope may, however, be turned into a very useful instrument by having the value of its readings estimated by comparison with an absolute galvanometer, and these readings arranged in a table either on the dial itself, or on a card fixed in a convenient position for casual reference.

Suppose for instance a galvanoscope be found to give deviations of

30	Degrees	for a	current of	1	mv.
38	,,	,,	,,	2	,,
45	,,	,,	,,	3	,,
56	,,	,,	,,	5	,,
68	,,	,,	,,	10	,,
75	,,	,,	,,	20	,,

we should have simply to make a table of these values, so as afterwards to be able to estimate *approximately* the strength of the currents used in absolute units.

The advantages of such a galvanometer in electro-therapeutics are numerous. It is a measurer of doses; by its means we are enabled to administer and prescribe quantities of electricity, as we do of any other therapeutical agent with the help of scales and weights. It is a registerer of objective and absolute quantities; it allows us to record in a manner useful to ourselves and others, for further reference and comparison, the current strengths used on different occasions for purposes of treament or diagnosis.

The number of cells used is no measure of the actual strength of current, because the electro-motive force of the elements themselves, and the resistances in the circuit vary considerably from time to time.

A galvanometer on the other hand, makes us entirely independent from these sources of variation. Whatever the kind of cells used, and the resistances in the circuit, we can always make sure that our current is of the desired strength by reference to the deflection of the needle. Further, the galvanometer enables us to test the state of the battery; and, if used in combination with the double

collector, to find out instantly any defective cell or connection in the battery, a most precious advantage, and which will be highly appreciated by those who are in the habit of using electricity frequently.

Again, the galvanometer is of great value in helping the physician to obtain clear ideas about electro-motive force, resistance and current-strength, especially if a rheostat be used conjointly. It is astonishing to find the utter confusion of thought which reigns upon these points, even in many text-books of medical electricity; and I need only remind the reader of the hopeless ambiguities attending the use of the words quantity, intensity, tension, and the like. Nothing is better fitted to clear them up than the practice of measuring electrical quantities.

Along with the use of the galvanometer, the currents may be advantageously tested by the operator by means of his own sense of touch. In many cases this will give him sufficiently accurate, at least subjective, information; with a little practice he will associate certain sensations with certain indications of his needle, and the two methods complete one another. There are occasions, however, when the galvanometer only is reliable or practicable—such as when we wish to increase or decrease the current without interruptions, or when very weak currents, hardly appreciable to the touch, are to be used. Again, the acquisition of the tactus eruditus requires here as elsewhere considerable practice and opportunities every one does not possess.

Finally, it must be clearly understood that the successful use of a galvanometer necessitates no electrical knowledge whatever; no more than the use of a watch, that of the mechanical principles which preside over its construction; so far from any previous familiarity with the laws of electricity being requisite, the intelligent use of measuring instruments is, as before stated, the best means for its acquisition.*

ARRANGEMENT OF ELEMENTS.

A SUBJECT of practical importance in itself, and which will serve to illustrate the principles established previously, is the arrangement of batteries. By this, we mean the mode of combining the cells of which they are composed. We may for instance, connect all the zincs together to the one terminal (negative pole), and all the coppers together to the other terminal (positive pole) of the battery; or again, join the copper of the first cell to the zinc of the second, the copper of the second to the zinc of the third, and so on, then attach the negative terminal of the battery to the zinc of the

* The subject of current measurements in electro-therapeutics has been the subject of a controversy in the "Lancet" (March, April and May, 1877), to which the reader interested in the question may refer.

first cell, the positive to the copper of the last. Finally, we may combine both methods and form, for instance, groups of cells, connected zinc to zinc and copper to copper according to the first methods, each group being treated as a simple cell, and connected with the next group according to the second method.

Cells united zinc to zinc, and copper to copper, are said to be united in simple (circuit) or in multiple arc; those united zinc to copper, to be united in compound circuit, or, shortly, in series.

According to a now exploded theory, the first arrangement is still sometimes called "for quantity," the second "for tension," or "for intensity." The truth is that both are for current strength, and what is called arrangement, for "tension" might as well be called for "quantity" when the external resistance is great. Take for instance, 20 Daniell's elements. The electro-motive force of each is very nearly 1 volt; and the internal resistance may be taken at 10 ohms. If we join them in series, we shall have a total electro-motive force of 20 volts; if we join them simply, we shall have an electro-motive force of 1 volt, that is, the same as if we used a simple cell, the only difference being that the 20 cells may be considered as forming one large cell, with plates of twenty-times the area of a single one. To use a rough comparison. If we pile up 20 bricks 1 foot in all dimensions we obtain a difference of level of 20 feet above the ground; if we put them side by side, we have a difference of level from the ground of 1 foot only, but an area of 20 square feet. Suppose now instead of bricks we have pieces of water pipe of the same size, and arrange them in the same way; in the first case we shall have one pipe 20 feet long and 1 foot square; in the second, a pipe 1 foot long and 20 feet square, It need not be pointed out that the amount of water these two pipes can transmit is very different.—The superficial analogy between the bricks and pipes and our 20 Daniells, is sufficient to illustrate what is meant by saying that, when arranged simply, the battery has an electro-motive force (difference of level) of only 1, whilst its total surface, that is conductivity, is multiplied by 20, that is again, its resistance, the reciprocal of conductivity, divided by 20; and that when arranged in series, its electro-motive force is multiplied by 20, whilst its conductivity is divided by 20 (that is, its resistance multiplied by that number). In the first case the whole electrical current has to pass from zinc to copper, that is, to overcome the resistance (diminished proportionally to their surface 20 times increased) of the liquid between them, only once; in the second it has to do it twenty times in succession. Each time it does so, on the other hand, it receives an increment of electro-motive force equal to the difference of potential between copper and zinc, *i.e.* of 1 volt.

Let us now return to the formula for Ohm's law, $C = \frac{E}{R + R'}$, our battery of 20 Daniells arranged 1st in series, 2nd simply, 3rd in groups, will give us a current, through an external resistance R':

A. Arranged in series: $C = \frac{20 \times 1}{(20 \times 10) + R'}$.

B. Arranged simply: $C = \dfrac{1}{\left(\frac{10}{20}\right) + R'}$.

C. Arranged, say, in four groups of five cells each:

$$C = \frac{5 \times 1}{\left(\frac{4 \times 10}{5}\right) + R'}.$$

Suppose three cases where R is respectively a part of the human body to be galvanised; a small portion of animal tissue to be electrolysed; and a piece of platinum wire to be heated for the galvano-cautery.

The resistance of a human arm, for instance, may be taken at 3000 ohms; that of the blood of an aneurism (the two poles being passed in) at about 8 ohms; that of the platinum wire at $\frac{1}{2}$ ohm. We can tabulate the results obtained in these three cases, with the three arrangements above mentioned:

ARRANGEMENT.	ARM.	ANEURISM.	WIRE.
A. Compound or in series.	$\dfrac{20 \times 1}{20 \times 10 + 3000}$ $C = \cdot 0062$	$\dfrac{20 \times 1}{20 \times 10 + 8}$ $C = \cdot 096$	$\dfrac{20 \times 1}{20 \times 10 + \frac{1}{2}}$ $C = \cdot 1$
B. Simple or in multiple arc.	$\dfrac{1}{\frac{10}{20} + 3000}$ $C = \cdot 00033$	$\dfrac{1}{\frac{10}{20} + 8}$ $C = \cdot 12$	$\dfrac{1}{\frac{10}{20} + \frac{1}{2}}$ $C = 1.$
C. Mixed, or in 4 groups of 5 each.	$\dfrac{5 \times 1}{\frac{4 \times 10}{5} + 3000}$ $C = \cdot 0017$	$\dfrac{5 \times 1}{\frac{4 \times 10}{5} + 8}$ $C = \cdot 31$	$\dfrac{5 \times 1}{\frac{4 \times 10}{5} + \frac{1}{2}}$ $C = \cdot 59$

The relative strength of the currents obtained in the three cases with each of the three arrangements, shows at once which of the latter is to be preferred, in the particular instance given, to obtain the greatest effect possible from the 20 cells. How then are we to find the best method of arranging a given number of cells so as to produce the greatest possible effect with a given external resistance? Multiply the number of cells (N) by the quotient of the external resistance R by the internal R′. The square root of the number obtained will indicate the number of the groups into which the cells must be arranged. It will be found that the most favourable arrangement of a given number of cells for giving the strongest current possible with a given external resistance, is to make the

internal equal, or as nearly equal as possible, to the external resistance.

Let us apply our formula $x = \sqrt{N \times \frac{R'}{R}}$ to the examples just given. In the case of the wire and aneurism the result is clear:

$\sqrt{20 \times \frac{\cdot 5}{10}} = \sqrt{1} = 1$ group. $\sqrt{20 \times \frac{8}{10}} = \sqrt{16} = 4$ groups.

But in the case of the arm we obtain:

$$\sqrt{20 \times \frac{3000}{10}} = \sqrt{6000} = 77 \text{(nearly.)}$$

This result seems at first sight anomalous. But what it means is this, that in order to obtain the most advantage from our 20 cells in a circuit with an external resistance of 3,000 ohms, we should divide them into 77 smaller cells; *i.e.*, that the current obtained by about 80 cells, each a quarter of the original cells, and consequently with four times the original internal resistance, is the strongest obtainable from any arrangement (including subdivision) of our 20 cells. Here also the internal resistance is found to be made as nearly as possible equal to the external, for $77 \times 4 \times 10 = 3080$.

Thus we may put down as a fundamental axiom that in order to obtain the strongest current possible with a given number of elements through various external resistances, we should be able to alter their arrangement with every change of external resistance, so as to make in each case the internal resistance equal to the external. This principle finds a direct application in galvano-caustics, where provision should be made that the internal resistance of the battery, that is, the combination of its elements, be always equal to that of the platinum wire used.*

CONSTANCY OF CURRENTS.

THE constancy of the current, that is the evenness of its flow during a certain length of time, depends upon two conditions:

1. The absence of changes occurring in the cells.
2. The absence of changes occurring in the external circuit.

These changes cannot be altogether avoided, but they can be neutralized to a great degree.

Changes within the cells depend upon the chemical action which is the very condition of the existance of a current. They consist in (*a*) diminution of the electro-motive force; (*b*) increase of the internal resistance; and (*c*) the occurrence of polarisation.

Polarisation is a phenomenon due to the evolution of hydrogen and oxygen in the cell. The hydrogen collects at the platinode,

* In arranging a battery for the cautery, it must not be forgotten that the resistance of a wire increases by about $\frac{1}{273}$ for every degree centigrade its temperature is raised. We must then make our calculation, not from the resistance of the wire when cold, but when raised to the temperature required. The resistance of a piece of platinum at low red heat (550°) is about twice, at white heat (1300°) six times greater than at 0°.

the oxygen at the zincode, and a counter current is generated from the hydrogen to the oxygen which may acquire such a strength as to neutralize completely the original current. It is usual, therefore, to interpose between the two metals a "depolarising" substance, *i.e.*, a substance that will combine with the hydrogen and prevent its accumulation on the negative metal. In the Daniell this substance is sulphate of copper, in the Leclanché peroxide of manganese, in the Grove and Bunsen nitric acid, in the Grenet bichromate of potassium. All these are decomposed by, and combine with the hydrogen, and so prevent the occurrence of polarisation. This they do more or less completely, and for a longer or shorter time; and as they are destroyed in the process, the depolarising power of the cell gradually diminishes with use. A fresh supply of the substance has then to be introduced from time to time.

Simultaneously with these phenomena, alterations take place in the electro-motive force and internal resistance. Both of these, as we know, remain constant only as long as the constituents of the cell are uniform in composition. But as the zinc is dissolved and fresh compounds are set free within the cell, these constituents are altered, electro-motive force falls, internal resistance rises: the cell becomes weaker. The rate of these changes is proportional to the activity of the cell, that is to the strength of the current used and the time during which it flows, *i.e.*, (to the quantity of electricity evolved). If therefore, a large and a small cell are put to the same service the larger will last longer, because there is a larger supply of materials within it.

For the same reason also polarisation is more efficiently neutralised in larger cells, which consequently are more constant. Medical batteries, unfortunately, require a large number of cells and must generally be made portable; that is medical elements must be small, and consequently less constant and durable,

The changes occurring in the external circuit are mainly :—

Oxidation of the wires, screws, electrodes, etc.; oxides are very bad conductors of electricity, hence their presence weakens the current.

Differences in the nature and amount of moisture of the electrodes used.

Differences in the resistance of the portion of the body included between the rheophores depending upon the moisture and thickness of the epidermis, the nature and quantity of tissues interposed, the occurrence of polarisation currents in the electrodes, and in the body, &c.

The importance of these sources of inconstancy can hardly be over-rated; the chief is the varying condition of the epidermis. They are difficult to avoid but can be met in two ways :—First, by correction; that is by the combined use of the galvanometer and current regulator, the number of cells in circuit being constantly adjusted so as to keep the needle steady. This explains itself, and is the system most readily adopted in medical batteries. Second, by elimination. This system consists in using a very large number

of cells and intercalating in the circuit a very large additional resistance;* any oscillations in the resistances of the body, electrodes, wires, due to the causes above described, become insignificant —nay the whole resistance of the body, etc., may be neglected in comparison to that additional resistance. Thus, if I wish to pass a current of medium strength say of 5 millivebers through a patient's body of which the resistance may be taken at 3000 ohms, I must use 15 Daniells (taken at 1 volt each), for $\frac{15}{3000} = \cdot 005$ current strength. The same current strength will be obtained from 250 Daniells through a rheostat resistance of 50,000 ohms: $\frac{250}{50000} = \cdot 005$. It is clear that if in this circuit I add the patient's body the whole additional assistance will only produce a difference of about $\frac{1}{16}$ of the whole current strength. Much more therefore will any of the oscillations spoken of above fall out of calculation, and the utmost constancy secured.

For purposes of diagnosis especially, the plan of using a larger number of elements with an additional resistance is invaluable as securing a great accuracy in the results, and effecting a great saving of time by making the observer independent from minute attention to the details of the operation, otherwise indispensable. The large numbers just mentioned are typical; but the principle remains the same when smaller batteries and smaller additional resistances are used. The advantage derived will always be proportional to the ratio between the additional resistance and that offered by the body.

As previously mentioned, currents impelled by a high electromotive force through a high resistance are called "currents of high tension" in the language of the old fashioned text-books. This is a convenient expression, and may be preserved if it be carefully divested from the exploded theories with which it is associated. The reader interested in the subject is referred to a paper of mine in the *Medical Times and Gazette*, Sept. 28th, 1877, on *The Nature and Therapeutical Value of Electrical Tension.* I may take this opportunity for correcting an error in that paper. Speaking of the wear and tear of the cells, I stated that it was proportional to the current used. This of course is incorrect, as there is obviously work lost as heating in the rheostat and the battery itself. But the small extra cost attending the use of high tension currents is of no consideration in presence of their great advantages.

DERIVED CURRENTS.

If two or more paths are opened to the current, as when for instance the poles of a battery are connected by two or more wires, the current divides itself among the wires in such a way that the strength of each branch current is inversely propor-

* Part of this resistance may obviously be made internal by artificially increasing the thickness of diaphragms, etc.

tional to the resistance of the wire; that is if the wires are of the same metal, directly proportional to their respective diameters; exactly the same thing occurs in a cistern provided with several exit-pipes, the amount of water flowing through each is directly proportional to the diameter of the pipes, or, if we suppose the pipes of equal diameter but unequally packed with pieces of sponge, inversely proportional to the resistance offered to its flow in the several pipes.

Let B represent the battery, and let the rheophore bifurcated at D convey the current to a rheostat R and to a part of the human body R′. A galvanometer is included in each of the derived currents, G, G′. Suppose the resistance R′ to be 2000 ohms. First make the resistance in R 2000 ohms, the galvanometers will indicate that the currents passing through R and R′ are equal. Next increase the resistance in R to 3000, 4000, &c.; the deflections show that the currents in R and R′ become as 2: 3, 2: 4, etc. Finally, diminish the resistance in R to 1000, 500, etc., and the currents assume the ratio in R and R′ of 2: 1, 2: ·5, etc.

Fig. 18

By inserting a third galvanometer into the portion of the circuit E B D, where the current is undivided it is easily proved that in every case the sum of the currents in R and R′ is equal to the current in E B D.

DENSITY OF CURRENT.

The density of a current is measured by the quantity of electricity flowing through a sectional unit of the area of the conductor in a unit of time. Thus if we send a current of the strength 1, (that is conveying 1 veber in the second) through wires 1, 2, 5, 10, square millimetres of sectional area respectively, it is evident that whilst in the first case 1 veber will pass through 1 sq. m.m. only ·2, ·5, ·1, veber will pass in the other wires through every square millimetre. In other words the densities of these currents bear an inverse proportion to the diameters of the conductors in which they flow. Here again the analogy between conducting wires and water pipes will assist in realising the nature of the phenomenon.

If then in the same circuit there occur differences in the diameter of the conductors, the density of the current at any point is, *cæteris paribus*, inversely proportional to the diameter at this point.

DIFFUSION OF CURRENT: DISTRIBUTION OF POTENTIALS.

When the rheophores of a galvanic battery are placed in contact with any two points of a conductor of any shape and size, the whole of the conductor is permeated with electrical currents, which

diffuse themselves in accordance with the laws of the derived currents, *i.e.*, which are the weaker the longer and more circuitous the course they take if the conductor be homogeneous; or, what comes to the same thing, the greater the resistance they encounter. It is evident that a conductor of any kind can be looked upon as consisting of layers of conducting substance thinning out towards the points of application of the rheophores. Each of these layers offers a passage to the current, which divides itself among them, (exactly as if they were wires) into derived currents of a strength inversely proportional to the resistance of their respective paths, and of a density inversely proportional to the sectional area of these paths. A glance at the diagram (fig. 19) where the lines of current from P to N subdivide the conductor into such imaginary layers will make this evident.

In order that a current should flow from one point to another, there must be a difference of potential between these two points. Hence different parts of a conductor through which a current flows are at different potentials. With a cylindrical homogeneous conductor, such as a wire, the case is very simple: such a conductor may be conceived as made up of a series of very thin disks, each of these disks transmitting the current from the disk preceding to the disk following it. Every part of such a disk would then be at the same potential, which potential would be intermediate between those of the contiguous disks. In other words, every point of the surface exposed by a transverse section of a wire is at the same potential: that is, such a surface is an equipotential surface. The case is more complicated when the conductor is not evenly pervaded by a current, such as in the case of the rectangular conductor represented in the diagram. The equipotential lines will be represented by the curves 6 6, 5 5, etc., 0 0, —1—1 etc., for which, however, I do not claim anything like geometrical accuracy. Suppose the battery C Z, (the internal resistance of which is negligible), has 14 volts electromotive force. The points P and N will then be at +7 and —7 volts respectively; and the distribution of potentials in volts along P N will be as indicated by the numbers, the middle point being at zero, whilst within the conductor itself the potentials will be found distributed, as indicated by the curves above mentioned.

FIG. 19.

Explanation of Diagram.—In the diagram a b c d represents a

rectangular conductor with which the rheophores of a battery C Z are brought into contact at the points P and N. The whole conductor is then permeated with currents, the general direction of which is represented by the lines joining P N. By means of an electrometer or galvanometer, it can be shown that the distribution of potentials in the conductor is somewhat as shown by the lines +6 6, +5 5, etc,, 0 0—1 1,—2 2, etc. If a b c d represents a piece of glass covered with a thin metallic film and dusted over with iron filings, when the electrodes are applied at P N, the filings will arrange themselves so as to have their long diameter along the equipotential lines 6, 6, 5, 5, etc. etc.

THE HUMAN BODY AS A CONDUCTOR.

Looked upon as a conductor of electricity, the human body is composed of a variety of substances of various specific resistances. Except the epidermis and its appendages all its tissues are more or less richly bathed in saline fluids; we know that solutions of salts are comparatively good conductors, and experiments show that the conductivity of the various tissues, muscle, nerve, bone, tendon, etc., is practically proportional to the quantity of liquid they hold. Dry epidermis is an insulator, imperfect, however, owing to the numerous sweat ducts which open upon its surface and act as conductors. On being soaked with water—or better still with hot salt and water—the epidermis itself becomes a conductor.

In order to explain the diffusion of the current in the body, we may compare the latter to a vessel bounded with poorly conducting material (the skin) and filled with a saline conducting fluid (the blood and juices generally) and unequally packed with porous non-conducting solids (mineral, albuminous, etc., constituents). Viewed in this light the following statements will be readily understood:

1. The chief resistance opposed to the current, in medical electrisation, is at the points of application of the electrodes to the skin.

2. Hence the strength of the current increases with the increased size of the rheophores.

3. The current circulates through the fluids of the organism: hence its distribution is not uniform as in a homogeneous conductor, but highly irregular and impossible to appreciate with any degree of precision.

4. The bones are the worst conductors. The blood and muscles the best. The central nervous substance conducts better than the nerve trunks.

5. Comparatively powerful currents are required to influence those tissues which being poor conductors themselves are surrounded with better conducting material, such as the nerves among the muscles.

6. "The resistance of the human body" is, strictly speaking, a meaningless expression. By that name is to be understood the resistance of two portions of the skin in contact with the electrodes

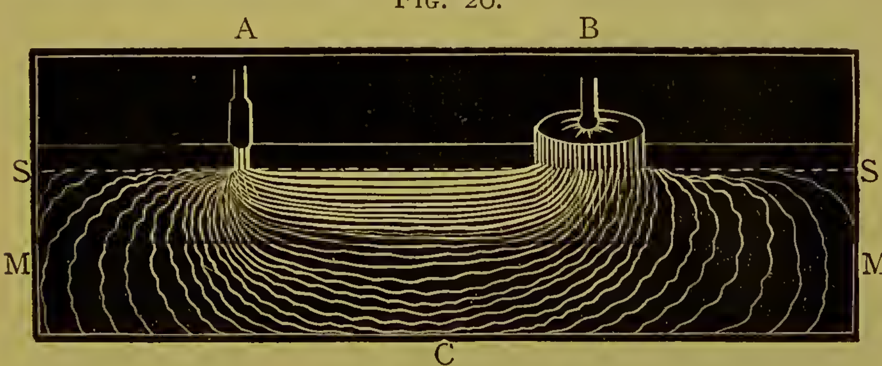
—the resistance of the intermediate portion of muscle or other tissues being almost negligible in proportion to the former.

7. Hence "the resistance of the body" will vary not so much according to the distance of the electrodes from one another, as to their diameter, the degree of moisture of the epidermis, its thickness at the point of application, the number of sweat ducts opened to the current, and the state of the cutaneous system, *e.g.*, a hot perspiring skin conducts far better than a cold dry one.

These considerations help to explain the prodigious discrepancies between the numbers given by various observers as to "the resistance of the body." The only reliable method of obtaining approximately correct results is, in my opinion, that of intercalating different portions of the body by means of electrodes of medium size into a circuit containing a large rheostat resistance, say 40 or 50,000 ohms, and observe the proportional diminution of the current strength thus produced. For only in this way can a multitude of sources of error be eliminated, otherwise inevitable.

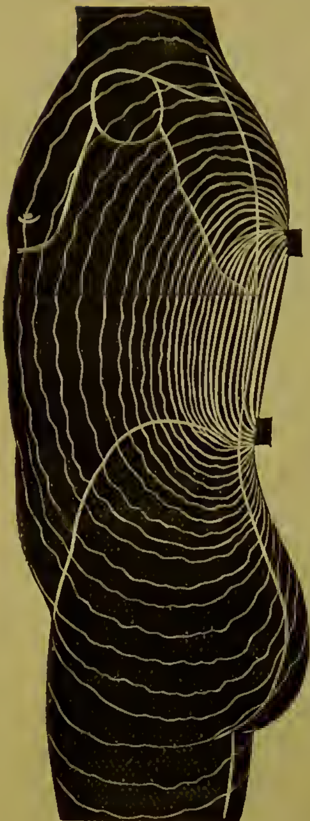
2,500 ohms may be assumed to represent the average resistance of the body in the usual medical applications, but no practical importance, except from the most general point of view, can be attached to this statement.

FIG. 20.



Explanation of Diagrams.—The diagram fig. 20 is intended to illustrate the following facts:—Two electrodes, A B of different sizes being applied to the skin, S, overlying a muscle, M, the current exerts the most powerful influence where it is the densest, that is under the smaller electrode. It diffuses itself over an indefinite area in the manner I have attempted to depict, but which the engraver has not very faithfully rendered. The shorter the distance between A and B, the greater will be the proportion of the current flowing through the tissues immediately between them; the longer the distance, the more it will diffuse itself through the whole of M; for as A recedes from B, it is obvious that the difference between the resistance offered by the direct path A to B, and the resistance offered by the more circuitous path, A C B, diminishes proportionally. Hence the practical rule that the nearer the electrodes, the denser the current (the more powerful the effect) in the tissues immediately between them.—Through the skin the current chooses the points of least resistance, *viz.*, the sweat ducts.

Fig. 21.



The diagram fig. 21 is intended to illustrate the fact that the current diffuses itself throughout the body whatever the points of application of the electrodes may be. Absolute localization is impossible. If A and B are the positive and negative poles respectively, the bulk of the current flows in more or less curved lines from A to B through the tissues enclosed between them. Externally to this interpolar region, the direction of the derived currents will be somewhat as shown by the wavy lines, that is opposed to that of the main current in the regions A to *a*, and B to *b*. Of course we assume here, for simplicity's sake, that the body is made up of a uniformly conducting substance.

It is of the utmost importance to bear in mind the diffusion of currents in electro-diagnosis, where it is the source of numerous fallacies. The occurrence of cerebral symptoms (giddiness, flashes of light, the "galvanic taste") when one of the electrodes is applied to the upper part of the back, is to be accounted for on the same principles.

MECHANICAL EFFECTS OF THE CURRENT.

When a current is sent through two vessels filled with a liquid and separated by a porous substance, such as an animal membrane, the level of the fluid sinks in the vessel in which the anode is placed, and rises in that containing the cathode. In other words, the current produces a transference of the liquid from the positive into the negative vessel. This phenomenon is known as osmosis. It naturally occurs between two dissimilar liquids; for instance between water and a solution of gum, the direction of the osmotic currents being from the lighter to the denser liquid; but the electrical current, when opposed to the natural direction, is sufficient not only to neutralise the phenomenon, but to reverse the order of its occurrence.

The amount of electrical osmosis grows with the resistance of the fluid acted upon, and is thus inversely proportional to the amount of electrolytical action. Thus it is very marked with pure water, and diminishes with the conductivity imparted to the liquid by salts in solution, etc.

When a current is sent through part of the body, we may readily suppose that such a transfer of liquids from cell to cell occurs on its path. But it is difficult to estimate even approxi-

matively, the therapeutical importance of osmotic phenomena. Yet they must be borne in mind when we try to account for the influence of the galvanic current on tissue-change, and for its notable power of promoting resorption in certain cases of effusion.

PHYSICAL EFFECTS.

The current has certain characteristic physical effects, such as the production of light and heat, and the induction of electro-motive force in neighbouring conductors.

Some authors speak of the "thermal" effects of electricity on the body, apart from the warmth produced by increased circulation. No such thing exists; medical currents are so weak, and the bulk of the body as a conductor is so great, that *a priori* it appears impossible that a sufficient quantity of electricity should be converted into heat as to raise perceptibly its temperature. Experiments, however, made with the most sensitive instruments have conclusively shown that no heat is evolved at the points of application of the electrodes.

Some authors, again, have laid much stress upon the existence of induced currents in the organism set up by every make and break of the galvanic current. The existence of such currents is doubtlessly a fact. But it is difficult to estimate their importance among the physiological effects of electricity. Dr. Radcliffe goes so far as to attribute to such induced or extra currents, the causation of contractions at the make and break of the galvanic current. But he falls into the curious error, fatal to his hypothesis, of assuming that it is the break extra current that is opposed to the battery current, instead of the make. That the primary galvanic current can call forth contractions independently of such induced currents accompanying its make and break, is abundantly shown by the phenomena of the reaction of degeneration.

CHEMICAL EFFECTS.

When the extremities of the rheophores connected with a galvanic battery are plunged in water, a more or less abundant evolution of gas is noticed; oxygen is given off at the positive pole or anode, hydrogen at the negative or cathode. This phenomenon is called electrolysis, or decomposition by electricity. The water is split up into its constituent elements. The same thing occurs when the solution of a salt is subjected to the influence of the current. Thus, if iodide of potassium is electrolysed, free iodine appears at the positive pole, and potash at the negative.

Similarly the chlorides, phosphates, sulphates, etc., suffer decomposition, the acid radical being set free at the positive, the alkali at the negative pole. If then we expose a piece of animal tissue, or albumen, to the action of the current the following phenomena will be observed.

1. The water it contained is decomposed; oxygen is set free at the anode, and an abundant froth, due to the more voluminous evolution of hydrogen is noticed at the cathode.

2. The salts split into acids at the anode and alkalies at the cathode.

3. The former along with the nascent oxygen oxidise the neighbouring tissues; the latter exert their peculiar caustic action. The tissues attacked form in the one case a hard dry eschar, in the other a soft moist mass, frothy by the admixture of hydrogen bubbles.

When a sufficiently powerful, or sufficiently prolonged current is applied to the human body, similar changes occur in the skin, at the point of contact of the electrodes. At the positive electrode an eschar is produced with an acid reaction; at the negative a vesicle, filled with an alkaline liquid. If the action is prolonged beyond this point, more extensive ulcerations take place, having the general characteristics of those produced by acids and caustic alkalies respectively.

Intimately connected with the fact of electrolysis is the existence of *currents of polarisation* in the organism at the moment of breaking of the galvanic current. These currents are opposed in direction to the original current, and can easily be demonstrated by placing the hands in two basins connected with the poles of a battery, and after a few minutes electrisation transferring them (after wiping) into two other vessels connected with a galvanometer. The needle indicates the existence of a current flowing in a direction opposite to that of the primitive current. The same phenomenon is observed in experiments upon pieces of animal tissue, and is obviously analogous to the "polarisation" of inorganic substances.

PHYSIOLOGICAL EFFECTS.

The physiological effects of electricity naturally fall under two heads, A, those due to the current itself; B, those due to changes in the current.

A. Physiological Effects of the Current.

1. *Electrotonus.*—When a constant current has been sent for a short time through a piece of nerve, the irritability of the nerve is altered in a peculiar manner. The phenomena observed are designated under the name of electrotonus. Without entering in any details upon this subject, which which will be found fully described and illustrated in any manual of physiology, I shall simply remind the reader that when a current is sent through a portion of a nerve the excitability of the nerve is diminished in the neighbourhood of the anode (positive pole), increased in the neighbourhood of the cathode (negative pole), and that these states are called anelectrotonus, and catelectrotonus* respectively.

2. *Refreshing Effects.*—The constant galvanic current has a marked "refreshing" effect upon nerve and muscle. More work can be performed when the muscles are under the influence of the current; the supervention of the sense of fatigue, and exhaustion is delayed.

* Often misspelt ca*th*electrotonus.

A muscle which has been tired out by repeated or prolonged action can be again and again restored by the application of the current. These facts can be easily verified by means of the dynamometer, comparing the results obtained first without, next with, the application of the current to the flexors. The experiments, however, must be frequently repeated so as to eliminate the numerous sources of fallacies involved in the method.

3. *Vasomotor Effects.*—The current has well marked vasomotor effects. These have been described as direct and indirect. Direct when due to the influence of the current applied to the parts themselves, where the desired result is to be produced; indirect when applied to the nervous trunks or centres containing the vasomotor nerves supplying those parts. It is probable that the lymphatics are also influenced in the same manner as the blood-vessels. In the latter the effects are marked: increased circulation due to their dilatation is evidenced by the redness and warmth imparted to the tissues. Under the name of the *Catalytical* effect of the current, Remak included the mechanical, chemical, and vasomotor effects. Therapeutically this is a convenient grouping, as no doubt these various factors each play a part in the often striking results obtained from galvanism in promoting absorption and tissue change.

The difference between the action of the positive and negative pole upon the vasomotor nerves seems to be mainly quantitative, the cathode being the more effective. The dilatation of the blood-vessels lasts a considerable time after the electrodes have been removed. It is preceded by a contraction of short duration.

B. Effect of Changes in the Current.

"Changes in the current" is merely a convenient expression for "variations in the potentials along the conductors through which it circulates." Such changes may be sudden or gradual.

Stimulation of nerve and muscle.—When the electrodes are applied to a muscle, or to its nerve, and a sufficiently powerful current suddenly sent through them, a momentary contraction is observed. During the period in which the current flows continuously, the muscle remains at rest; but another contraction occurs when the current is broken. Generally speaking we may say, that contraction is, within physiological limits, proportional to the suddenness, and to the amplitude, of the change in the current strength.

Physiologists have shown that when a current is alternately made and broken in a motor nerve, the contractions which occur in the muscles, supplied by that nerve vary also in their occurrence according to the direction of the current. When the current is descending or centrifugal (that is, the positive pole being the nearer to the nerve centres, the negative to the periphery), contraction occurs on making the current whatever be its strength; when ascending or centripetal (positive pole the nearer to the periphery, the negative to the centres) contraction takes place on making the current of weak, on breaking it if strong. For further details the

reader is referred to the ordinary text-books of physiology. The following table is usually given:—

	Descending.		Ascending.	
	Make.	Break.	Make.	Break.
Weak	C	—	C	—
Moderate ...	C	C	C	C
Strong... ...	C	—	—	C

As a general deduction from this "law of contractions," we may say that the descending current acts more energetically upon the motor nerves.

The opposite is found to hold for sentient nerves. The ascending current acts more readily upon them, sensation being most marked at the make of such a current. The sensation produced is of the kind peculiar to the nerve acted upon; thus, flashes of light are perceived when the optic nerve is stimulated; sounds when the acoustic; smell when the olfactory; pain when the nerves of common sensation. The electrical stimulus, then, acts most readily when travelling along the nerve in the same direction as the normal nervous wave.

Vasomotor Effects.—Interrupted currents stimulate vaso-motor as well as other nerves. Hence the primary result is a contraction of the arterioles and diminution of the blood supply. But these effects are only temporary, and are followed by the opposite state, that is increased circulation, and dilatation of the vessels. This is explained by three considerations:—

First: After the forcible contraction of the muscular elements of the vessels there occurs a reaction. They pass into a paretical* state from which they only gradually recover.

Second: The voluntary muscles which may have been stimulated at the same time contract, and as a necessary consequence, the circulation of the part is increased.

Third: There may have been simultaneous stimulation of the cutaneous nerves. It has been shown that this alone is sufficient to call forth hyperæmia of the subjacent parts. Thus faradisation of the skin, where the action is strictly localized to the superficial parts, is followed with an elevation of the temperature of the limb acted upon.

Effects on unstriated muscles.—These need only be referred to here. Muscles of organic life are readily stimulated by galvanisation and faradisation. It is doubtful whether this fact has hitherto been taken full advantage of for therapeutical purposes.

* Paresis is a convenient expression for partial loss of power.

Differences between Direct and Indirect Muscular Stimulation.

It is important not to lose sight of the differences which exist in the reaction of voluntary muscles to electricity, according as the stimulation is direct or indirect, that is according as the muscular tissue itself or its nerves, be excited. In the state of health, purely muscular stimulation is unattainable, owing to the diffusion of nerve fibres and endings in the muscular substance which render the localisation of the current to the muscular tissue impossible; but in certain pathological states where these nervous elements are atrophied, as for instance a few days after the traumatic lesion of a motor nerve, and before the muscle has undergone any notable change, such a stimulation is readily effected.* It is then observed, first, that the contraction is delayed and runs a more protracted course; second, that in order to produce such a contraction, the amplitude of the change in the current strength may be less, but that this change must be spread over a larger area, and last an appreciable time (*i.e.*, a certain *quantity* of electricity is necessary to stimulate muscular tissue). This is why in peripheral paralysis farado-muscular contractility is lost, and that even galvano-contractility disappears when the interruptions of the current are too frequent.

Matteuci has shown by accurate experiments that to stimulate a frog's nerve, a current of $\frac{1}{10000}$ of a second's duration was sufficient; and of such a strength that the quantity of electricity conveyed by it represented the energy set free by the oxidation of seven billionths of a milligramme of zinc. Unfortunately comparative experiments upon electro-muscular irritability are yet wanting.

PHYSICAL DIFFERENCES BETWEEN GALVANISM AND FARADISM.

The fundamental difference between the galvanic and the faradic current is, that whilst the former consists in the continuous flow of electricity, the latter consists in a succession of exceedingly short currents (or "sparks"). Hence, therapeutically, we may look upon the faradic current as a mere series of instantaneous changes of potential, without any electrical quantity. Its sole effects then, will be those of a stimulant of nerves. It is devoid of all the other effects, chemical and physiological, enumerated above.

In addition to this main difference, some points of secondary importance may be noted.

Every single shock from the faradic coil is really double: the current is suddenly made, and immediately broken again. In other words, the potential of the tissues acted upon is suddenly raised from 0 to x immediately to fall back to 0 again.

* It is a well known fact that in a traumatic paralysis for instance, voluntary motion returns before farado-muscular contractility. But it must be observed that the muscle may then be made to contract by faradising the nerve above the seat of lesion. It must then be assumed that the freshly restored portion of the nerve, though capable of transmitting stimuli originating above it, has lost, owing to some unknown peculiarity, the susceptibility of direct faradic stimulation; and that it is only when it has regained this susceptibility down to its very terminations, that intra-muscular faradisation meets with a response.

The "high tension" of faradic currents is usually put down as a characteristic; this of course depends entirely upon the fineness and length of the wire used for the coil. It is, however, difficult to understand how this "tension" can, as some authors assert, have any influence upon muscular contraction. Owing to the exceedingly small quantities of electricity conveyed by the faradic current, the effects due to its diffusion are very slight.

The number of interruptions per second in the faradic current is, with the usual apparatus, large. Consequently during its whole passage, the muscles are kept in a state of contraction.

The alleged difference between the galvanic and faradic currents, due to the fact that the former flows in one direction, the latter in two directions constantly reversed, is more theoretical than based upon facts. First, it applies to the secondary induced current only. Second, the arguments used against Duchenne's assumption that the difference of physical action between the primary and secondary was specific, and the experimental proofs adduced to show that precisely the same results were obtained by the use of either coil, provided the physical conditions (length and thickness of wire, etc.) were the same, obviously apply to the subject under consideration.

EFFECT OF POLES AND OF DIRECTION.

When we come to the therapeutical application of the data supplied to us by electro-physiology, we are met at once by a great difficulty. The conditions under which we must act are totally different. It would seem at first that nothing could be simpler, for instance, than to verify the law of electrotonus on a living man, yet it is far from being so; and this result has been obtained only by dint of carefully planned experiments and repeated trials. The difficulties to be contended with depend upon the fact that it is almost impossible to localise the currents sufficiently in the parts to be experimented upon. This will be readily understood by referring what has been said about the diffusion of the currents in the organism. The effects ascribed by physiologists to the direction of the current in a nerve can hardly be expected to manifest themselves fully in therapeutical practice because first, the strength of the current is very much diminished owing to its diffusion in the surrounding tissues; second, because as shown in the diagrams, that direction is not uniform; the nerve is influenced under each electrode by currents flowing in the opposite senses. These and other considerations, among which is the great success obtained by the polar method of investigation, have considerably strengthened the views of those who, after Brenner, attribute the results obtained, not to the direction of the current, but to the specific influence of each pole. A bitter controversy, not yet appeased, has been raging between the partisans of this "polar method" and the adherents of the "direction method." There is no doubt that both sides have gone too far, and it is possible, from a purely practical standpoint, to effect a compromise between the extreme views. Considering how little we know of the pathology

of many diseases in which electricity is pre-eminently successful, and of the relative importance of electrical influences (electrolytical, electrotonical, vasomotor, etc.) in these diseases, we must preserve, in therapeutical matters, an empirical attitude, and base our methods upon grounds of convenience and upon clinical results, rather than upon physiological experiments and theory. When physiology agrees with clinical observation so much the better; when it disagrees, we must endeavour to reconcile them by finding the differences of conditions which may account for the discrepancy. As a matter of fact, both methods are adopted in the following pages: the polar method in what concerns diagnosis, the direction method for treatment.

The polar method consists in eliminating the effects of one of the poles by placing it upon a distant "neutral" point of the body, whilst the one whose effects are sought is applied to the organ to be investigated or treated. The brilliant results obtained of late years by the application of this method to electrical investigation as well as its superior practical convenience, do not allow of any doubt as to its superiority for purposes of electro-diagnosis. On the other hand, nothing can be clearer than the almost complete failure which has attended, in therapeutics, the attempts to verify the physiological basis of the polar method. The anodyne and stimulant effects, for instance, attributed to the positive and negative pole respectively, are rarely realised in practice. In most cases it would seem that the curative effects are due more to the general influence of "the current" properly applied both as to strength and place, than to any specific action of pole. The same remark, it must be confessed, may frequently be applied to the direction. It must be acknowledged also that, when considered from a practical point of view, the direction method and the polar method often differ more in name than in deed; and there seems to arise from some quarters a tendency to reconcile the two. What concerns us more particularly here, however, is the fact that in order to obtain satisfactory results in electrical treatment, a systematic and rational application of the current is absolutely necessary. Nothing can be worse than the desultory, meaningless manner in which the thing is too often done. It is for electro-therapeutics as for all the other arts: first, master an approved method; then, but only then, pass on to experiments and original improvements. In the following pages, clearly defined rules of practice are given which have been found efficient in competent hands. Let us hope these will prove faithful guides in the practice of many; and lead them to the successful employment of one of the most powerful therapeutical agents we possess.

CHAPTER II.

APPARATUS.

GENERAL OBSERVATIONS ON MEDICAL BATTERIES.

The first point to consider in reference to a galvanic element is its electro-motive force. It is evident that this is the main circumstance which regulates the number of cells to be used in medical practice. The E. M. F. of a Grenet, Bunsen and Grove is about 2 volts; that of a Leclanché 1·5; of a Clamond-Gaiffe 1·3; of a Daniell and chloride of silver 1; of a sulphate of lead ·6. The E. M. F. of single fluid cells, is difficult to estimate as it varies greatly from time to time. When freshly charged the Smee may be taken at ·8, the zinc carbon at 1·4. It is obviously impossible to convey any sense by speaking of "so many cells," their nature must be specified, and unless supposed to be in full working order their E. M. F. at the time.

But this is not all. The resistance of different cells varies greatly. Thus for instance, the simple fluid cells have no resistance to speak of, 1 or 2 ohms, or less when put in presence of the body. The R of the ordinary Leclanchés may be taken at 10 ohms. A battery of 50 would then have an internal resistance of 500, an appreciable factor in medical matters. Then again, we have the chloride of silver and Daniell, which as constructed by Gaiffe and Siemens, have a very sensible resistance amounting to 20 ohms or more. In fact I have chloride of silver cells of 180 ohms, 20 of which would thus have a greater resistance than the human body.

From what is said in other parts of this book, it will be readily seen that the internal resistance of batteries for medical purposes is of far more practical importance than might be concluded from the silence of most electro-therapeutical writers on this point.

The essential quality of a galvanic battery is constancy, and this depends, *cœteris paribus*, upon the energy of the depolarising body which it contains. Single fluid cells have no special provision made for depolarisation; the rough surface of the platinised silver or carbon prevents to a certain extent the deposition of hydrogen upon the plate; but this is imperfect. As we have said the Leclanché occupies a middle position between these and the true depolarising cells, such as the Daniell.

Another point of view from which we must consider medical elements is their portability, *i.e.*, their size and weight. By far the most portable is Gaiffe's chloride of silver, which contains practically no liquid, and can be placed in every position without ceasing to work. Next come the Leclanché and Daniell, the latter as modified by Dr. Onimus. Last the Smee and zinc carbon which are very heavy and exposed to irretrievable injury if upset. The latter danger is to a great extent remedied in Salt's battery.

Durability is an important item to be noticed here. What renders the Grove or Bunsen impracticable is the necessity of a daily

recharge. A Leclanché on the other hand, and better still a Gaiffe-Clamond, owe their excellence to the extraordinary durability which distinguishes them. No chemical action takes place when the circuit is opened, and in the case of the larger sized cells, years may elapse, and yet they remain efficient. Next in order Gaiffe's chloride of silver element must be mentioned, which is calculated to furnish, through the resistance of the body, about 800 hours of actual work without recharging. Dr. Onimus' sulphate of copper battery is very durable too. The Muirhead and single fluid cells require much more frequent recharging. The single fluid cells are very easily recharged. The Muirhead much less so. The silver can also be recharged by the owner. The drawback attending the Leclanché is that, when recharging is necessary, the work must be done by the patentees, and several weeks may elapse before the possessor sees his battery again.

Some minor considerations must also be kept in mind in trying to form a comparative estimate of the merits of the various elements used for medical purposes. Thus, for instance, if the electrodes are left in contact, whilst the current is on, a few hours will suffice to make a complete wreck of a Leclanché, whilst a Daniell will be not much the worse for it. On the other hand, as we have said, the Leclanché like the chloride of silver does not require any such mechanism to throw them out of action, as is required for a single fluid element, since no chemical changes can go on when the circuit is opened. In the Daniell there occurs a diffusion of the liquids through the diaphragm which necessitates recharging after a while, even when the battery has not been used. It must be said, however, that the rate of this diffusion occurs in an inverse ratio to the resistance of the diaphragm. It is rapid in the Muirhead; much slower in the Siemens Remak and Onimus sulphate of copper elements.

A practitioner's battery should be able to develope a force, when required, of at least 60 volts. The number of elements should then be Leclanché's or zinc carbon 40 to 50, Daniell's, chloride of silver, or Smee's 60 to 80. The internal resistance should be sufficiently large to enhance the constancy of the current, without, however, detracting too much from its strength, 20 to 30 ohms per cell is a convenient resistance. But the internal resistance may, with advantage, be made higher still, provided a proportional increase in the number of cells be no objection. When, as occasionally happens in diagnosis, a more powerful current is required than a battery of the usual size can give, a small supplemental battery of 15 to 20 cells is conveniently put into the circuit.

The battery should be provided with the accessories necessary for rapid and accurate graduation of the current strength (dial, rheostat, &c.), means of measuring that strength (galvanometer), and means of breaking, reversing the current (interruptor, commutator). These and the other accessories are considered in detail further on.

The elements should be protected from accident, and at the same time easily got at. The connections inside the battery must be pro-

tected against any corrosive action, and thoroughly insulated. It will be found very convenient to have the external metallic fittings silver or nickel plated. Copper fittings must have their surfaces kept free from oxide by scouring with emery paper or the use of fine files.

Whilst on this subject, I think a few remarks on the chief causes of failure in batteries may conveniently be added. First, if the failure is gradual, it will probably be found that it is due to exhaustion of the cells. In this case, the remedy is obvious: they must be replenished. This is not the place for entering into the details of the operation, which vary according to the kind of battery used. Instructions on this point are usually given by makers to the buyers of their instruments.

Second, the failure is more or less sudden. The source of the mischief may be, 1, in the cells, 2, in the connection between the cells, 3, in the connections between the cells and the element board, 4, in the conductors and electrodes. In order to find out which of these parts is at fault, a methodical investigation is necessary, and the best is to proceed by elimination. The electrodes applied to the skin do not yield any current: disconnect them and apply the ends of the rheophores. If nothing is felt, then apply the moistened fingers to the terminals of the element-board. If the signs of the current fail here also, apply the fingers again to the poles of first and last cell. Having thus localised the source of mischief, it must be remedied accordingly. Electrodes must be cleaned or mended; rheophores must be changed; faulty connections rectified; exhausted cells replenished.

The rheophores are often at fault, usually at the points of attachment to the electrodes. With ordinary telegraph wire it can hardly escape immediate discovery; but in the old fashioned silk covered conductors, the metallic threads may be completely broken, and yet nothing appear externally.

Defects in the element-board and its connections are not always so readily discovered and rectified; the less so, the more complicated the structure. A certain amount of familiarity with the anatomy of his battery ought to be possessed by the practitioner, so as not to be entirely dependent upon the instrument maker for rectifying every little hitch that is sure to occur at some time or other.

This remark applies with equal force to the accidents to which the cells themselves and their connections are liable. In order to discover the defective point the collector may be used, so as to determine up to which cell the battery works; and then carefully examine from that point if any connection is loose, or corroded; if any cell leaks, or works irregularly, salts creeping up, zinc being eaten away, etc. All this of course requires some practical knowledge of electrical matters in general, as well as of the details of the battery used, but the labour expended in acquiring this knowledge is sure to repay amply in time. Many disappointments will be avoided and time and money saved by him who can dispense with external assistance in the management of these little matters.

Whenever heavy work is required from a battery, and portability is not essential, every advantage will be gained by establishing a

fixed battery of large elements. It is quite true that as far as current strength is concerned nothing is gained by the use of large elements, and that the idea, still surviving in some minds, that their therapeutical effects are greater "because they give a greater quantity of electricity" is a mere relic of antiquated theories. But it is equally erroneous to attribute to them some mysterious faculty of "giving more painful shocks" than small cells. As a matter of fact, all the conflicting statements about the merits or demerits of this or that kind of elements are based upon imperfect observation. As long as experimental proof is not forthcoming, we are bound to assume that the effects of a constant electromotive force, whatever its origin may be, acting through the same total resistance must be absolutely the same. But to return:

1. Large cells are to be preferred because the surfaces of the plates being larger polarisation does not occur so readily.

2. Large cells containing a larger amount of material, last longer without recharging.

3. Large cells are as a rule less likely to get out of order, being better made.

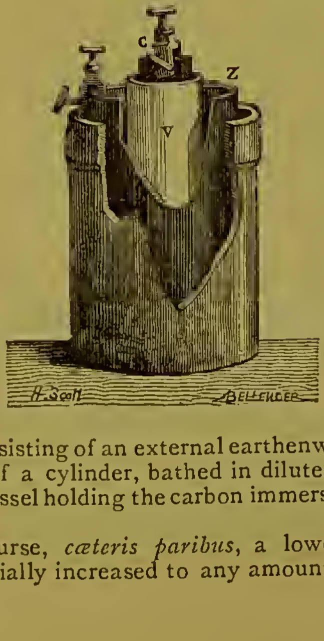
4. Large cells are cheaper than small ones proportionally to the amount of work they furnish.

The advantages of a fixed over a portable battery are obvious. It is not exposed to the dangers of being upset or injured. It is less likely to fail at a critical moment, and if much used, is markedly more constant. If injured it is easier to repair. It gives much greater scope for a convenient disposition of the accessories, and element board, and allows the use of a larger number of elements with high internal resistance.*

THE BUNSEN AND GROVE ELEMENTS.

The Bunsen element, consists of an earthenware vessel filled

Fig. 22.



Gaiffe's Bunsen element, consisting of an external earthenware vessel which contains the zinc, Z, in the shape of a cylinder, bathed in dilute sulphuric acid. Within the zinc stands a porous vessel holding the carbon immersed in strong nitric acid.

* Large cells have of course, *cæteris paribus*, a lower resistance than small ones; but this can be artificially increased to any amount by the simple interposition of a proper diaphragm.

with dilute sulphuric acid in which is plunged a cylinder of amalgamated zinc. Within the cylinder stands a porous cell of baked clay filled with strong nitric acid, and containing a prism of carbon. The action of a Bunsen is as follows: the zinc is attacked by the sulphuric acid, sulphate of zinc being formed. The oxygen formed by the electrolysis of the water remains about the zinc whilst the hydrogen is transferred by the action of the current, through the porous cell and the nitric acid, towards the carbon. Before it reaches it, however, it combines with some of the oxygen of the acid which is reduced to nitrous acid, as evidenced by the evolution of the characteristic red fumes. As long then as there is a sufficient quantity of acid to oxidise the hydrogen, a constant current will circulate.

Grove's cell is essentially the same as Bunsen's, the main difference being the replacement of carbon by platinum. Its chemical reactions are the same. The currents supplied by these two cells are very powerful, their electromotive force being about 2 volts, and their internal resistance being capable of being reduced to a fraction of an ohm. Once charged, they work very regularly for a few hours. But the unpleasant fumes they evolve, and the difficulty of manipulating the strong acids restricts their use considerably. Their application in electro-therapeutics is limited to the galvano cautery.

THE SULPHATE OF COPPER ELEMENT.

The original form of this element is the well known Daniell, the most extensively used of all cells. It differs from the Bunsen by the substitution of copper, and a solution of sulphate of copper for carbon and nitric acid respectively. Here the hydrogen on meeting the solution precipitates metallic copper and sulphuric acid is formed.

Many modifications of details of construction have been devised to meet special ends. The following have been used in electro-therapeutics. The Becker-Muirhead consists of a rectangular vessel with a porous partition separating the liquids. The cells are usually arranged by tens in oblong boxes. A battery of 60—80 is necessarily very bulky and suitable only for work at home. The cells require cleaning every month or two when regularly worked; and when not in use are the seat of chemical action which necessitates frequent recharging. This is owing to the internal resistance being unnecessarily small. There is then every reason for breaking through the traditional orthodox saying, that the Becker-Muirhead, (whatever its merits be for telegraphy, etc.,) is the medical battery *par excellence.*

The Siemens-Remak cell has in this country a historical rather than a practical interest. The porous diaphragm is here replaced by a thick layer of paper-pulp; saw-dust, sand, felt, etc., have also been used. The resistance is thereby greatly increased and the durability of the cell notably improved, but the sulphate sooner or later finds its way to the zinc and necessitates periodic cleanings and refilling, a somewhat complicated process.

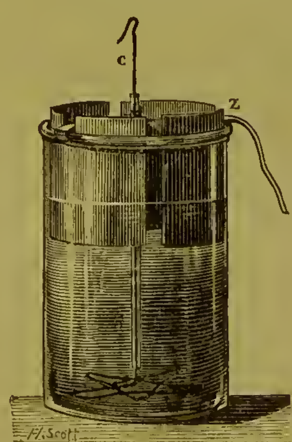
In order to provide a continuous supply of sulphate of copper, several contrivances have been imagined; in the Meidinger cell for instance, a vessel filled with crystals and with its mouth downwards is disposed as in the figure.

FIG. 23.

Gaiffe's Meidinger element B, is a glass vessel, with a neck dipping into the porous vessel containing the copper pole. The crystals and saturated solution with which it is filled before being inverted into the cell, keep up the supply of sulphate of copper constantly renewed.

The Callaud (gravitation) cell does not contain any diaphragm.

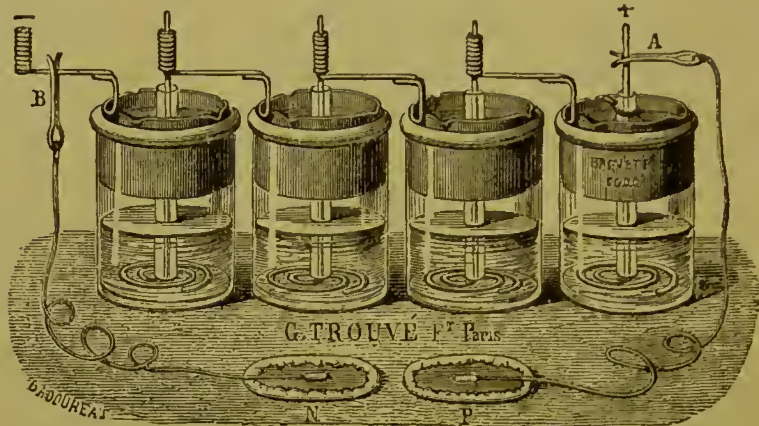
FIG. 24.



Gaiffe's Callaud element, a copper wire C, encased in a glass tube, in its middle portion, and bent into a proper shape stands in the middle of the cell. A plate of zinc is bent so as to fit in the upper part, water is then poured to the requisite level, and crystals of sulphate of copper dropped in. In virtue of its gravity the inferior layers of the liquid—a saturated solution of the sulphate—remains distinct from the upper into which dips the zinc.

The superior specific gravity of the solution of sulphate of copper is taken advantage of, and the two liquids are simply superposed. Of course this precludes the possibility of using the cell for any but stable battery. The chief merit of these elements is their cheapness; they do not cost more than sixpence each.

FIG. 25.



Four Callaud-Trouvé gravitation elements arranged in series.

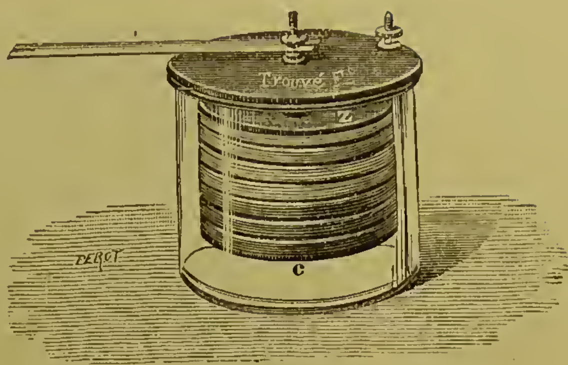
FIG. 26.

A battery of 15 Callaud-Trouvé elements in a box. The rheophores are connected by means of clips to the wires binding the elements together.

Dr. Onimus has brought several improvements in the construction of medical sulphate of copper elements. He speaks very highly of the following cell:—The external vessels consist of a large test tube, with a flat bottom upon which rests a disk of copper.

The upper part is occupied by a cylinder of zinc. A piece of glass tubing closed at one end with a disk of gun-wadding, and filled with crystals of sulphate of copper, stands in the centre of the test-tube, and the whole is filled with water. When once electrical action is thoroughly set up (this is effected by short-circuiting the battery for a few hours) the cell works steadily for

Fig. 27.



Trouvé's new Daniell element.—A disc of zinc at the top, and a disc of copper at the bottom are separated by a thick pad of blotting paper. The upper half is moistened with sulphate of zinc, the lower, with sulphate of copper solution.

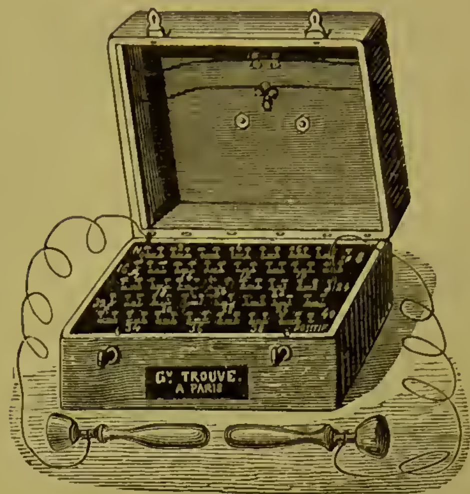
a very long time without any other care being taken of it, than dropping a few crystals in the centre tube from time to time, and water sufficiently to make up for evaporation.

Trouvé of Paris, has recently made a thoroughly compact and portable sulphate of copper element, which has the great advantage of not containing any liquid capable of being spilt. It consists of a disk of copper and a disk of zinc separated by several thicknesses of bibulous material. The pad is moistened with water, and then its inferior half is dipped in a strong solution of sulphate of copper. When not in use, it has only to be exposed to the air in order to dry, and so is not exposed to unnecessary wear.

Fig. 28.

Battery of 40 Trouvé's Daniells.—The element board carries a galvanometer, a reverser, and a collector composed of two halves, working the corresponding halves of the battery, so as better to distribute the wear of the elements. The single elements are arranged as shown at the top of the plate, and are suspended in the under surface of the element board. To recharge the battery, lift the element board, and dip the lower half of the elements (after drying them in the air) in a copper vessel (supplied with the battery) containing a hot saturated solution of the sulphate of copper. The battery is then recharged.

FIG. 29.



A simpler form of the same battery.—The dial is replaced by a pin-and-hole collector.

THE CHLORIDE OF SILVER ELEMENT.

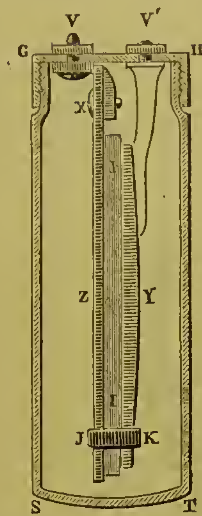
ZINC and silver are the metals used as electrodes; chloride of silver is the depolarising agent.

Stöhrer has made a battery of such elements. The general construction is the same as in his zinc-carbon battery. The cells consist of test tubes containing at the bottom some chloride of silver, and filled with dilute acid. The electrodes are in the shape of a silver wire fixed to the bottom, and a cylinder of amalgamated zinc to the upper half of the tube.

Messrs. Muirhead and Co. of Westminster, make chloride of silver elements which might advantageously be introduced into medical practice. They consist of a wide flat-bottomed test tube filled with dilute acid. The stopper is made of paraffine into which the electrodes (a rod of zinc and wire of silver) are fixed. The chloride of silver is cast, in the shape of a solid cylinder, around the silver wire. These cells work exceedingly well, as testified by Dr. Warren De La Rue who has fitted up a battery of 10,000.

Gaiffe of Paris, has devoted considerable pains to the improvement of the chloride of silver element, and brought it to a very high state of perfection. A cylindrical box of vulcanite, with a top that screws down hermetically, contains a plate of zinc, and a wire or plate of silver surrounded with fused chloride of silver. The zinc and silver are separated by a pad of bibulous paper, which, when moistened, contains all the fluid necessary to work the cell to exhaustion. A reference to the figures will make the details of the construction clear.

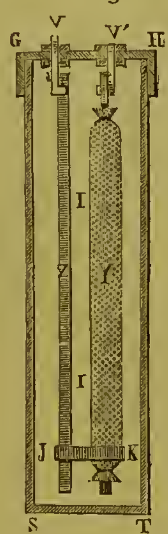
FIG. 30.



GAIFFE'S CHLORIDE OF SILVER ELEMENT.

G, H, S, T, vulcanite cell. The top screws on; and carries two metallic pieces V, V′, forming the poles to which are fixed, Z, a plate of zinc, and Y, a shallow silver cup filled with chloride of silver. The two are separated by a pad of moistened bibulous paper, I; the whole being fastened with an elastic band, J, K.

FIG. 31.



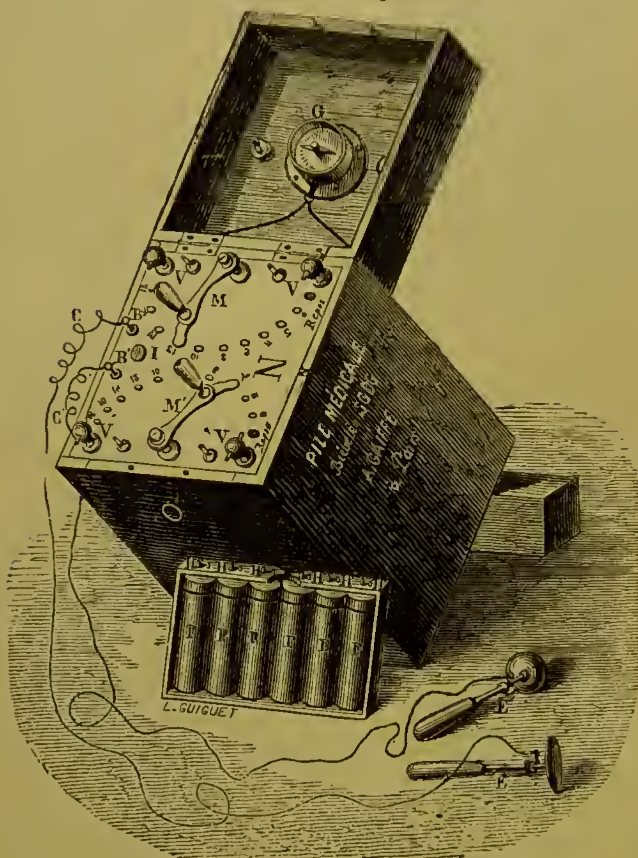
In the other form, the silver electrode is in the shape of a rod, surrounded with fused chloride of silver. The whole is contained in a muslin bag, Y. The other references are as in the previous figure.

In order to recharge the cell, unscrew the top of the cell, remove the elastic band, disconnect the zinc and silver electrodes, fill the silver cup with chloride of silver, put in a fresh zinc and pad of blotting paper, moistened in three per cent solution of chloride of zinc. Secure with the Indiarubber band, dip the whole in the exciting liquid, and fasten the lid. In the other form of element it is good to have some spare silver rods and chloride ready for use in a muslin bag. The whole operation takes but a very few minutes. If long unused, the zinc is liable to become encrusted with oxide; it is then simply necessary to scrape its surface and moisten the pad with a few drops of water.

The cells are made of two sizes; the larger is only $3\frac{1}{2}$ inches long, by $1\frac{3}{8}$ in diameter, and weighs but two ounces; it is used for working coils, etc. The smaller size is mainly used for galvanic batteries. The experience I have had of these elements is most favourable. Their electro-motive force is about the same as the Daniell's, 1·03 volt,* and they give a very constant current. As regards convenience they are by far the most portable cells ever constructed, and last a long time without requiring cleaning or re-charging, which operation is very simple, and can be carried out by any intelligent person. The only drawbacks of the silver cells are their elevated initial cost (the working is cheap enough, all the reduced silver being recovered) and for this country at least, the disadvantage of not having the prepared materials for recharging at hand.

M. Gaiffe has made me a battery of 60 such elements, of which

FIG. 32.



GAIFFE'S CHLORIDE OF SILVER BATTERY.

G, Galvanometer fixed on the lid, with its conducting wires. The connection is established through the hinges. The advantage of this arrangement is, that when the battery is shut, the needle does not rest upon the pin, and does not wear it out uselessly.

The element board carries a double collector with the handles, M, M′. The metallic buttons are marked, 0, 2, 4, etc. The reophores are attached at B′, B′. V, V, V, V, screws fastening down the element board. When not in use the handles rest on the dark buttons marked "Repos." The commutator is left out; the interruptor marked I.

The cells F, F, etc. are arranged in rows, in trays. The positive and negative poles of each cell, H, H, etc. protrude through the upper part of the tray which is placed standing in the box. The inferior surface of the element board carries a number of springs, each of which presses upon one pole, and so the connection is established. A drawer at the bottom of the battery contains the accessories.

Size of 60 celled battery: 13 × 7 × 9 inches; weight, 15 pounds.

* According to the latest measurements of Dr. Warren De La Rue.

I can speak in terms of the highest praise. It has stood during many months the double test of periods alternately of great activity and of complete rest; and of travels of more than 2,000 miles, during part of which it shared the fate of ordinary luggage, and has never yet given any signs of becoming weaker, or of being otherwise out of order. I am not aware of any other battery which combines to the same extent, durability, portability, and efficiency.

THE PEROXIDE OF MANGANESE ELEMENT.

This element, known as the Leclanché from its patentee, was first suggested by De la Rive. It consists of zinc and carbon as electrodes, peroxide of manganese as depolariser, and solution of salammoniac or common salt as excitant. The chemical changes which accompany the evolution of electricity in the cell are that Zn, $2\ NH_4\ Cl$ and $2\ MnO_2$ are changed into $Zn\ Cl_2$, H_2O, $2\ NH_3$ and Mn_2O_3. As in the chloride of silver element, no chemical change whatever occurs whilst the cell is not in actual use.

The electro-motive force of the cell is about 1·5 volt, that is, equal to one and a half Daniell. But it must be noticed that it is a *constant* element only in a different sense of the word altogether. A Grove or Bunsen will give when short circuited for several hours a very powerful and absolutely constant current; a Daniell will give a weaker, but equally constant current for several days under the same circumstances. They are the constant elements *par excellence.* But a Leclanché if short circuited, polarises in a few minutes to such an extent as to lose almost all its efficiency. But if circuited through a high resistance, say 2 or 3 thousand ohms, it gives a fairly constant current for a reasonable time—a few hours;* when partially polarised, it recovers itself after a short period of rest. It is then pre-eminently suited to intermittent work through high resistances—the very conditions met with in electro-therapeutics. What further enhances its merits is the fact, already stated, that when the circuit is broken all chemical action spontaneously ceases, requiring no lifting up of plates, etc., which is an inevitable complication in the use of elements containing an acid. It must not be concealed, however, that the small sized Leclanchés for medical use do not always work properly, and that owing to secondary actions, or the creeping up of the salts, they occasionally strike long before exhausted by use. This applies also notably to the small iron cells. This drawback joined to the difficulty of recharging has somewhat lowered the expectations raised on the first appearance of the Leclanché in electro-therapeutics.

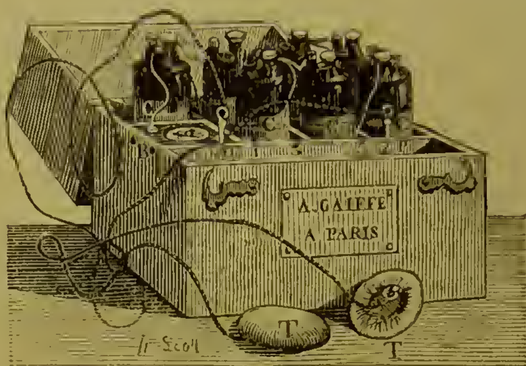
Several modifications have been brought to the manufacture of the manganese element. The familiar medical element of the Telegraph Company consists of a black vulcanite cell divided into two compartments containing the zinc and the carbon. A small aperture, closed with a cork at the top allows of charging with the solution.

* I found that a battery of 60 Leclanchés after working continuously through 6000 ohms for 48 hours was but slightly weakened.

Beetz, of Munich, has fitted up a portable Leclanché battery, the cells of which consist of test-tubes; but the details need not be entered upon here. Both the English makers, and Gaiffe, of Paris, make Leclanchés in glass cells of various sizes. A late improvement has been to combine the carbon electrodes with the peroxide of manganese by making them into one compact cylindrical mass; the necessity of a porous diaphragm is thus obviated. (See fig. 40.)

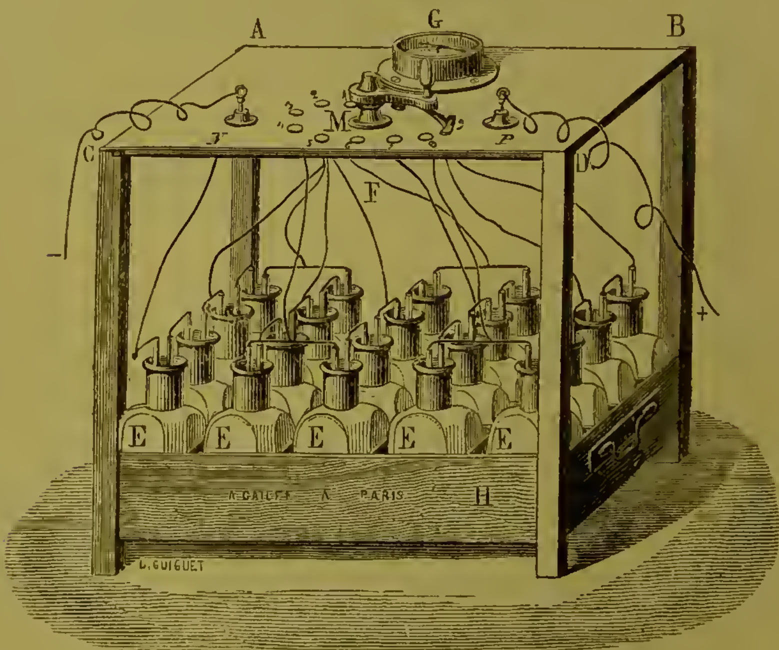
A large number of batteries are being now fitted up by different makers with the Leclanché element, of which some illustrations are here given.

FIG. 33.



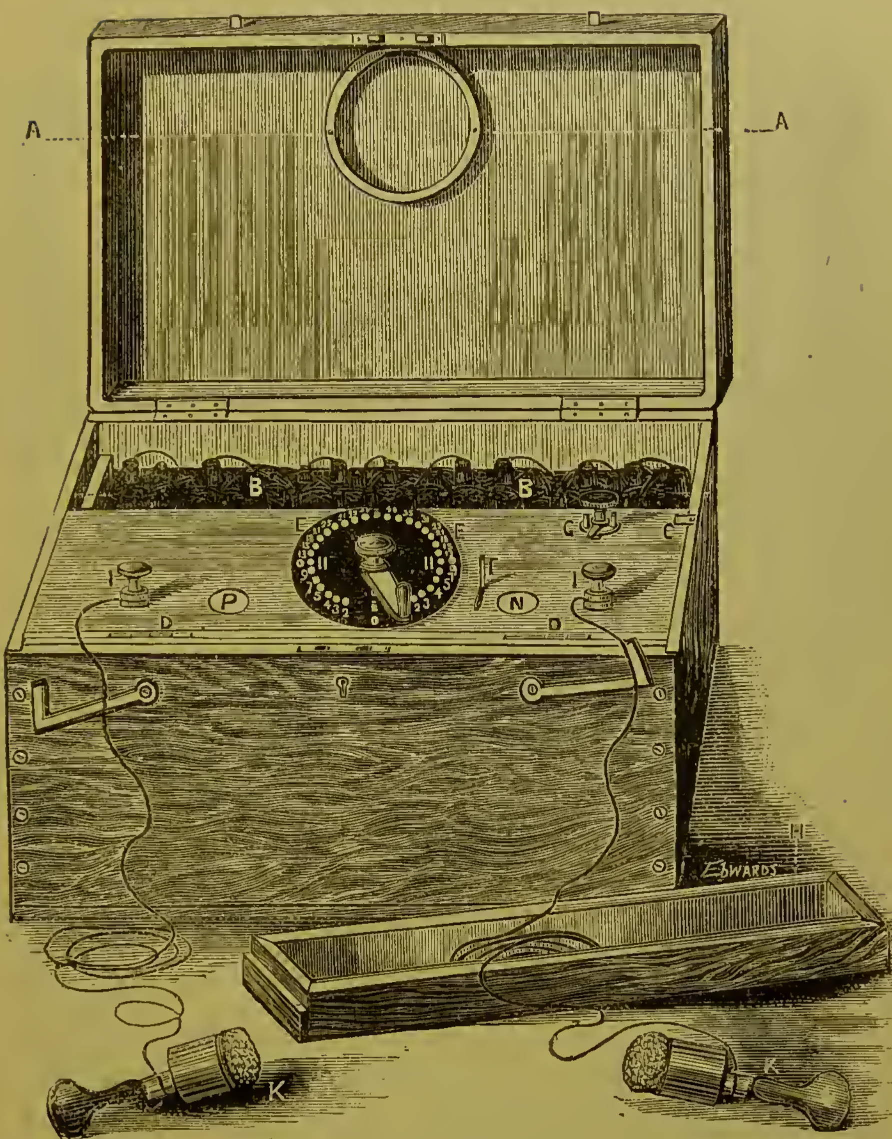
Battery of Leclanchès (or Clamond-Gaiffes) in a plain deal box with pin and hole collector, and simple galvanoscope, suitable for patients who electrise themselves. The figure represents a battery of 7 cells only; but larger batteries of 20, 40 or more cells can be had, constructed upon the same principle.

FIG. 34.



Battery of 20 Leclanchés E, E, &c. (or Clamond-Gaiffes) showing the connections. The element-board carries a simple collector M, a galvanometer G, and the binding screws. The case H, is an open framework, suited for hospital or house-work.

Fig. 35.



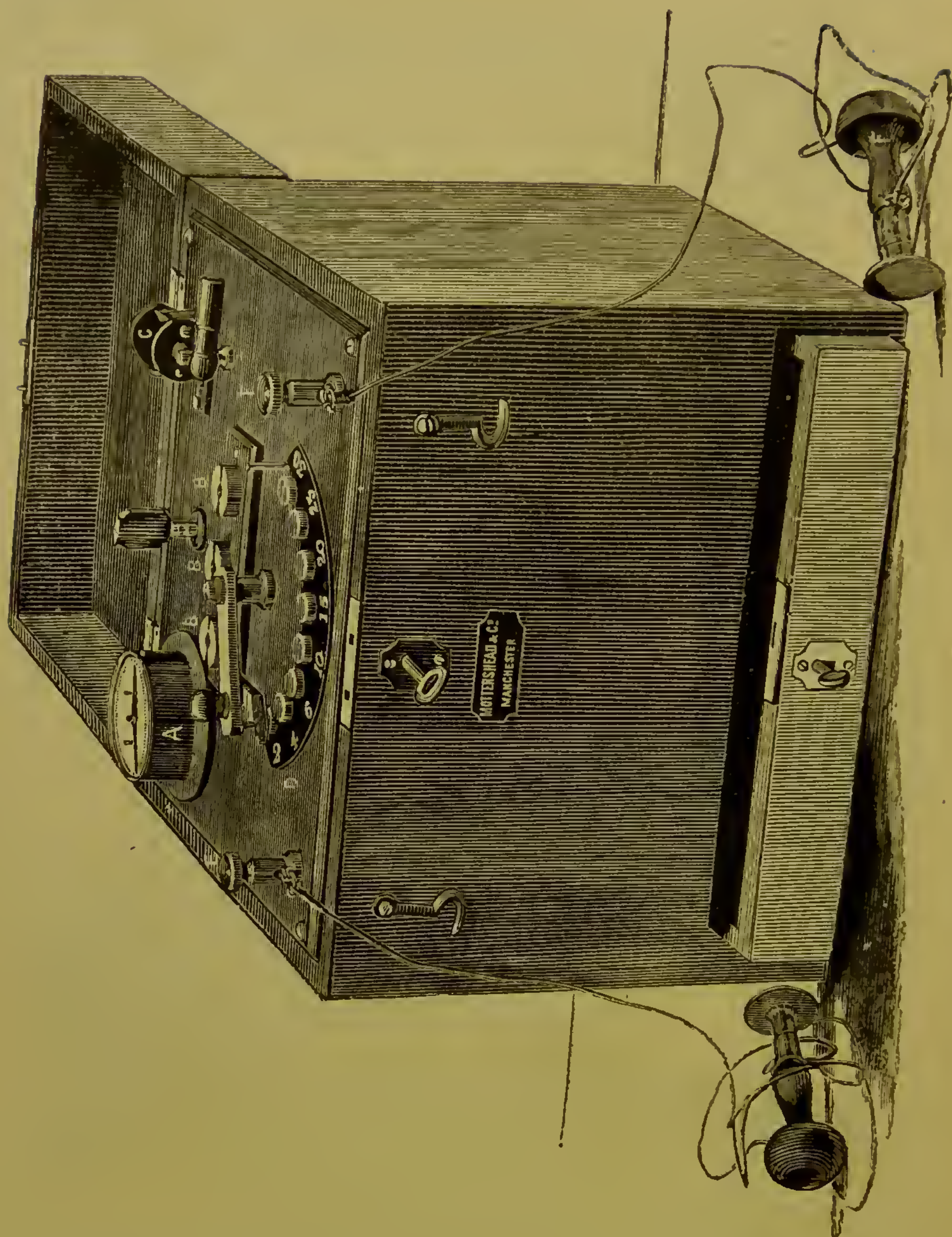
Battery of 40 Leclanchés, with Dr. Tibbits' dial and commutator
Size: 15 cells: length $8\frac{3}{4}$ inches; breadth $6\frac{1}{2}$; depth $8\frac{3}{4}$: weight: 16 pounds.
30 cells: ,, $10\frac{1}{2}$,, ,, $8\frac{3}{4}$; ,, $8\frac{3}{4}$: ,, 28 ,,

F. Handle of the commutator. The letters P and N are seen through a hole in the element board, and indicate at a glance which of the binding screws I, I is positive, and which negative. On moving the handle F the letters change place.

A guard A on the lid prevents the battery being shut before the handle of the dial has been brought to O.

G. Interruptor.

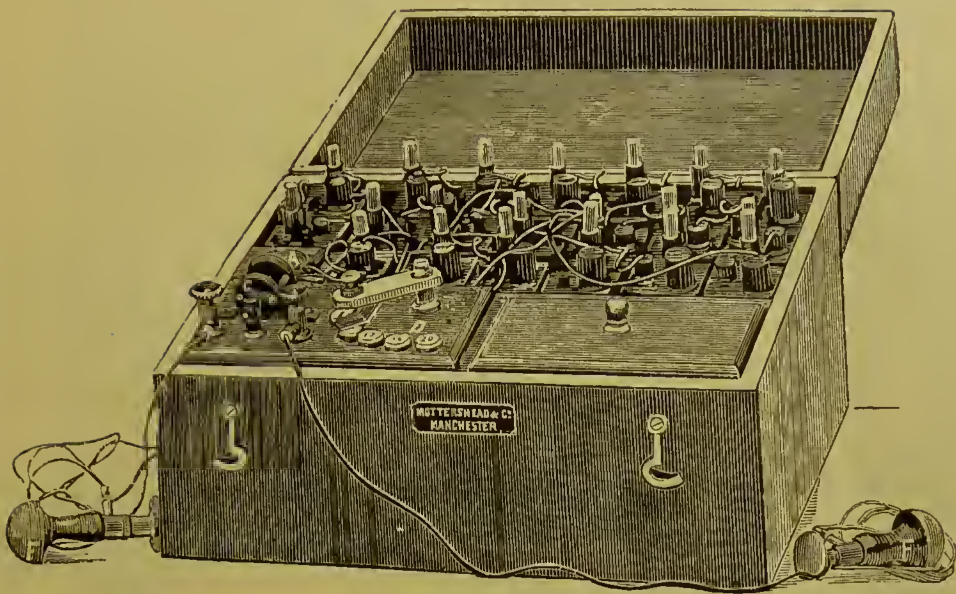
Fig. 36.



Battery of 30 Leclanchés.—The element-board carries a dial collector D; a revolving galvanoscope A; a commutator C; and a set of shunts, B, B, B, by means of which series of cells can be cut off, so as to avoid throwing the main wear upon the first few, EE binding screws. The accessories are electroplated.

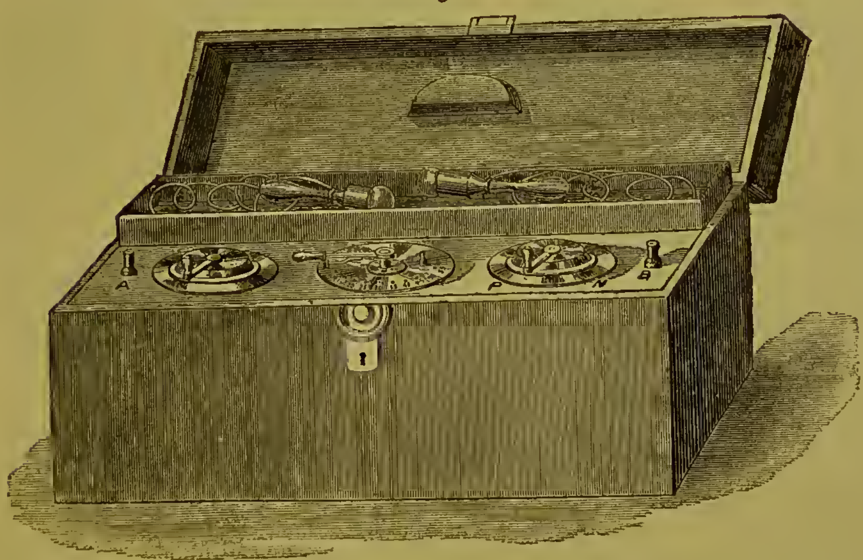
Size: 30 celled: length $9\frac{1}{2}$ inches; breadth $8\frac{1}{2}$; depth 10: weight: 22 pounds.
50 celled: „ 16 „ „ $8\frac{1}{2}$; $9\frac{1}{2}$: „ 33 „

Fig. 37.



A battery of 20 Leclanchés of simpler construction.
Collector D; Commutator C; Galvanoscope A.
Size: length 11 inches; breadth 8½; depth 6.
Weight: 13 pounds.

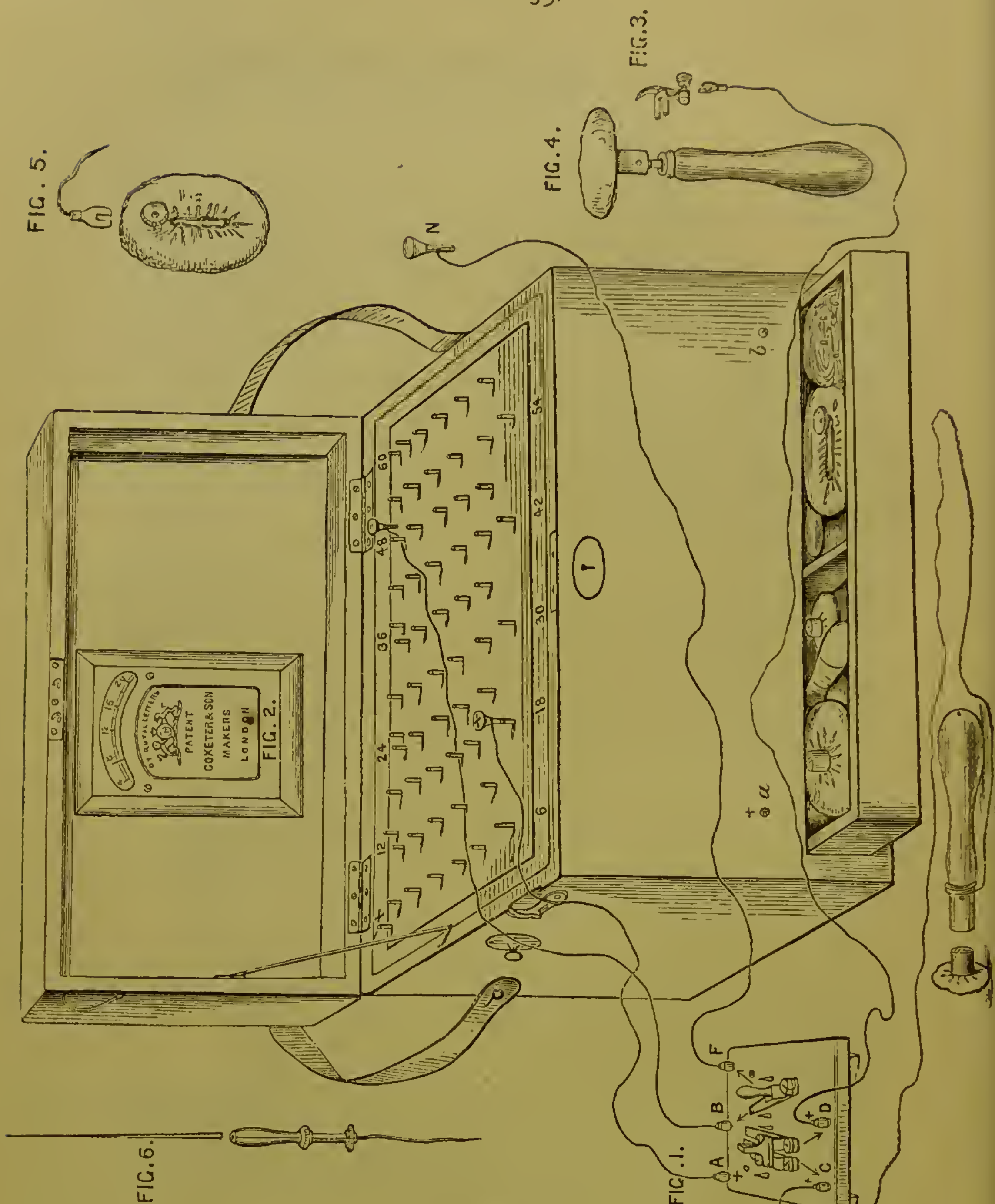
Fig. 38.



The Leclanché Company's medical battery of 55 cells.

The element-board carries a dial collector, a toothed-wheel interruptor, and a commutator. Vulcanite sponge holders are kept in the compartment provided for the purpose.

FIG. 39.



Mr. Coxeter has lately introduced a manganese element in which the carbon is replaced by platinum. The obvious advantage of this modification, is that it allows of the cells being smaller and lighter. Fig. 1. represents the current commutator and alternator modified for the purpose of increasing the current-strength by means of the pin-and-hole collector without break. Fig. 2 is a new form of galvanoscope, which acts in any position, vertical or horizontal, figs. 3 and 4 are representations of the component parts of the interrupting handle. The electrodes 4, are carbon disks mounted in nickelised fittings. Fig. 5. Tin plate.

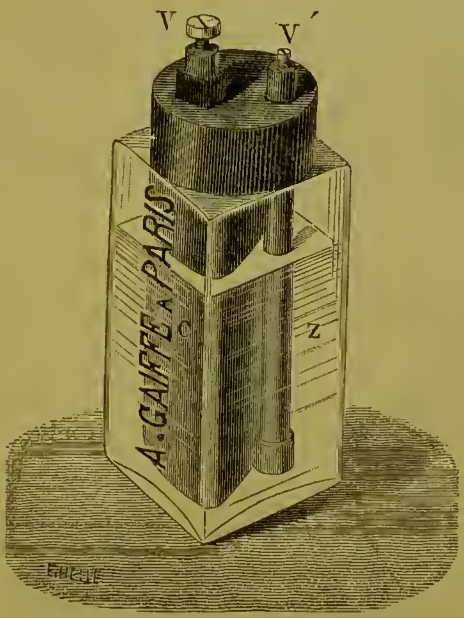
THE PEROXIDE OF IRON ELEMENT.

This element, known as the Gaiffe-Clamond, is mainly a Leclanché in which iron is substituted for manganese.

The superiority claimed for this cell is that it is more constant than the manganese element, and that the peroxide of iron, having the property of re-oxidising itself in presence of air, need not ever be changed. A battery of small Gaiffe-Clamonds can furnish medical currents for 2 or 3 hours daily, without any perceptible polarisation occurring; if the element be middle-sized, 8-10 hours daily work is obtainable.

The construction of the Gaiffe-Clamond is in every way the same as the Leclanché.*

Fig. 40.



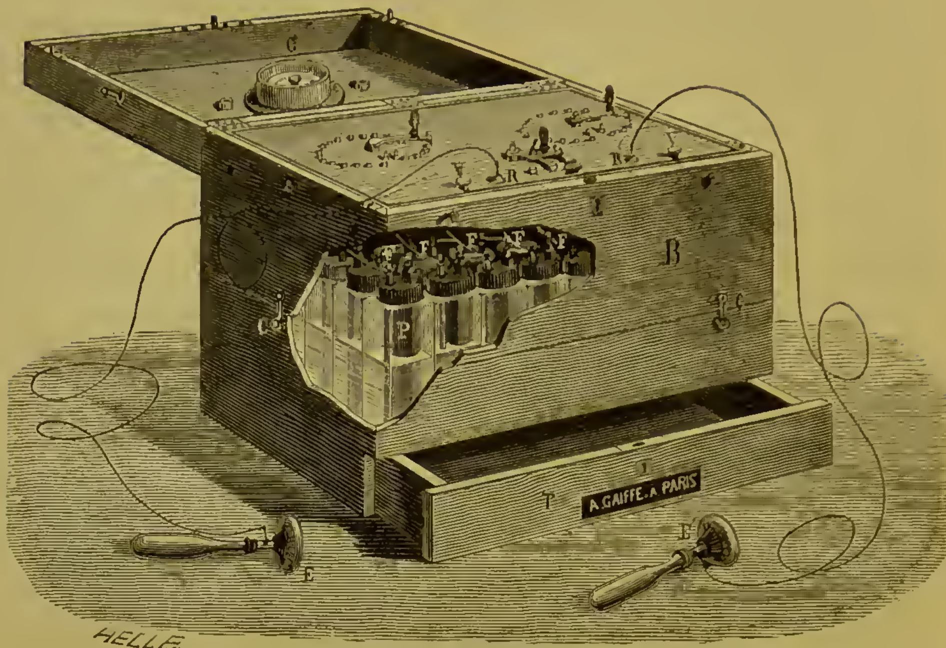
The Clamond-Gaiffe element. Z, zinc rod; C, carbon surrounded with sesquioxide of iron, dipping in the chloride of ammonia solution. V V' screws for connection.

Gaiffe constructs two models of batteries with iron elements. The one (obtainable of Mottershead in Manchester) has a simple pin and hole collector. The other is more complete as shown in the illustration.

* I feel bound to say here, that experience has not justified the expectations laid upon the iron element. For some hitherto unexplained reason, secondary actions are readily set up in it which soon destroy it. M. Gaiffe has, however, lately introduced an improved Leclanché for medical purposes, cheaper than, and in some respects superior to, the English article, and which can readily be substituted for the iron cell in batteries.

I have personally a great dislike for the method adopted by English makers of soldering the intercellular connections and bedaubing the whole with a thick layer of tar. Gaiffe's cells are furnished with screws (fig. 40) which allows of their being readily disconnected and examined.

FIG. 41.



Gaiffe's peroxide of iron battery.—The element board carries a double collector, a commutator and interruptor as described elsewhere. V, V, are the bolts for securing the board, which is hinged so as to allow a ready inspection of the elements. The lid carries a galvanometer G.

The case is separable into two halves for facilitating the repairing or refilling of the cells when necessary. The hooks c, c, secure the two halves together. A portion of the case is removed showing the arrangement of the cells B, and the connecting wires F. A drawer is provided for containing the rheophores, electrodes, etc.

FIG. 42.

Battery of 20 Gaiffe-Clamond elements, with simple pin and hole collector, and galvanoscope A. B, B, tin plates covered with wash leather.

Size: 20 celled: length, 12 inches; breadth, 8; depth, 6. Weight: 16 pounds.
50 ,, ,, 18 ,, ,, 11 ,, 6. ,, 37 ,,

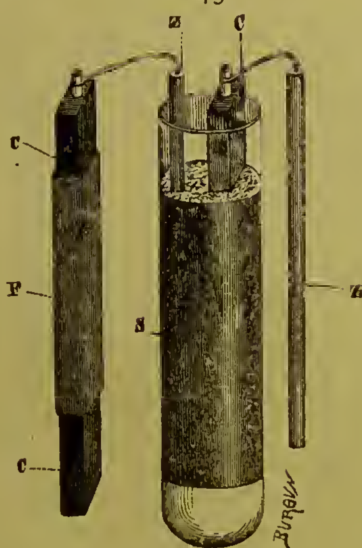
THE SULPHATE OF LEAD ELEMENT.

This cell has been used, among others, by Duchenne but is now practically abandoned, though yielding a current of very fair constancy. Its electro-motive force, however, is very low, being only ·54 volt, or just half a Daniell.

THE SULPHATE OF MERCURY ELEMENT.

This element, also called after the name of its inventor Marié-Davy, consists usually of a zinc-carbon pair, the carbon extending to the bottom of the cell and dipping into a layer of bisulphate of mercury. The cell is filled with water which slowly dissolves the

Fig. 43.

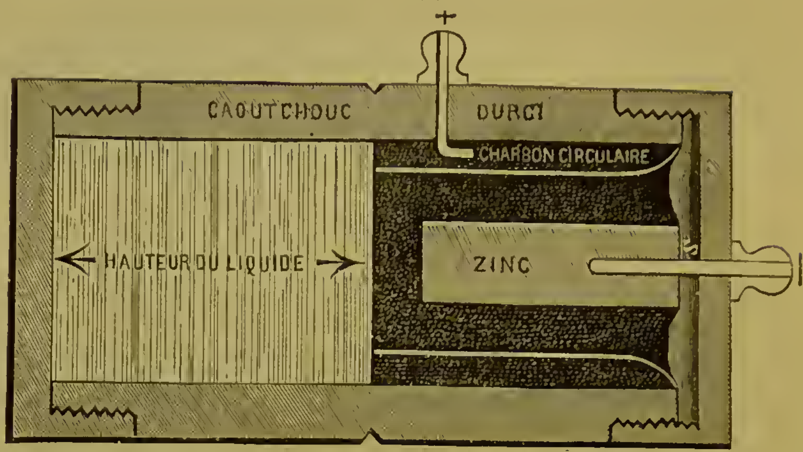


Gaiffe's sulphate of mercury cell.—A zinc rod and a plate of carbon C, dip in a large test tube filled with saw-dust, S, moistened with acidulated water. At the bottom there is a thick layer of sulphate of mercury.

salt. Metallic mercury is thrown down when action is set up. The cell is very constant when worked through high resistances, and its electro-motive force is the same as the Leclanchés.

Trouvé of Paris, has made an ingenious portable mercury cell which enters into action only when turned upside down. The cell is hermetical, and very well adapted for working induction coils.

FIG. 44.



Trouvé's hermetical element.—The upper half of the vulcanite cell is occupied by the circular carbon and rod of zinc as shown in the figure. The lower half is filled with a solution of bisulphate of mercury. When now the cell is placed on the side, the liquid comes into contact with the zinc and carbon, and enters into action.

The sulphate of mercury cell is also applicable to galvanic batteries; but is not superior to the iron or manganese element for this purpose. Its great drawback, when not hermetical, is the creeping of the salts, and consequent destruction of the connecting wires.

SINGLE FLUID ELEMENTS.

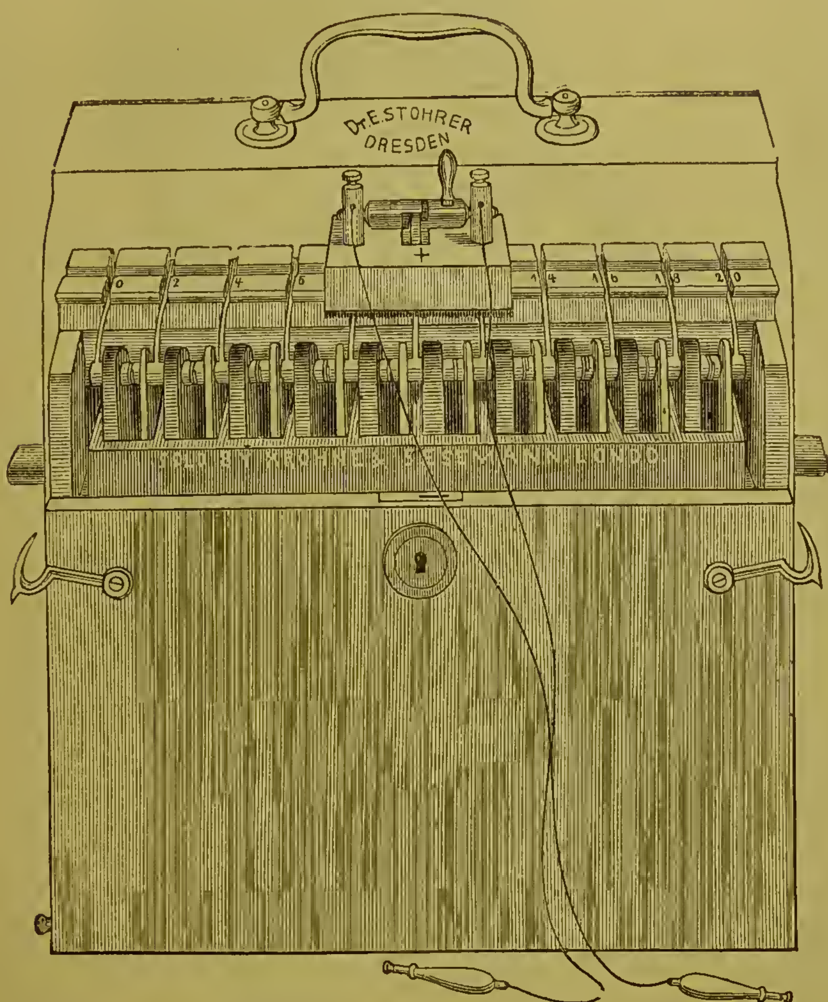
Zinc platinum element.—This element, known as Smee's, consists of a plate of zinc, and a plate of platinised silver dipping in dilute sulphuric acid. Platinized silver is used on account of the less tendency hydrogen has to accumulate upon a surface of finely divided metal. In Frommhold's battery platinized lead is used, being cheaper.

The Smee has enjoyed considerable popularity in this country, but like the zinc-carbon is gradually giving way before the improved depolarising elements with higher internal resistance.

The zinc-carbon element.—This element, known as Walker's has been popularised in the medical world by Stöhrer, a pair of zinc and carbon plates dip in a weak sulphuric acid solution (1 in 10 or 20 parts of water). Its electro-motive force is higher than the Smee's; and like platinized silver, the carbon owing to its rough surface offers some slight opposition to the adhesion of hydrogen bubbles, and thus polarisation is somewhat delayed. Messrs. Mayer and Meltzer whose name has been long associated in this country with the zinc-carbon element, are very wisely endeavouring to substitute for it in their batteries a constant element. Whilst fully recognising their superiority for *electrolytical* purposes, we are compelled to acknowledge that single fluid cells are essentially unfitted for medical applications.

The Bichromate of potash or Grenet element.—This is a zinc-carbon element in which the addition of bichromate of potash to the exciting liquid gives a higher electro-motive force, and a higher constancy, as it acts as a partial depolariser. The Grenet is largely used for working induction coils and is well adapted to this purpose, as it gives a very powerful current for a moderate length of time, and has a very low internal resistance. In Stöhrer's induction apparatus chromic acid replaces the bichromate of the usual Grenet.

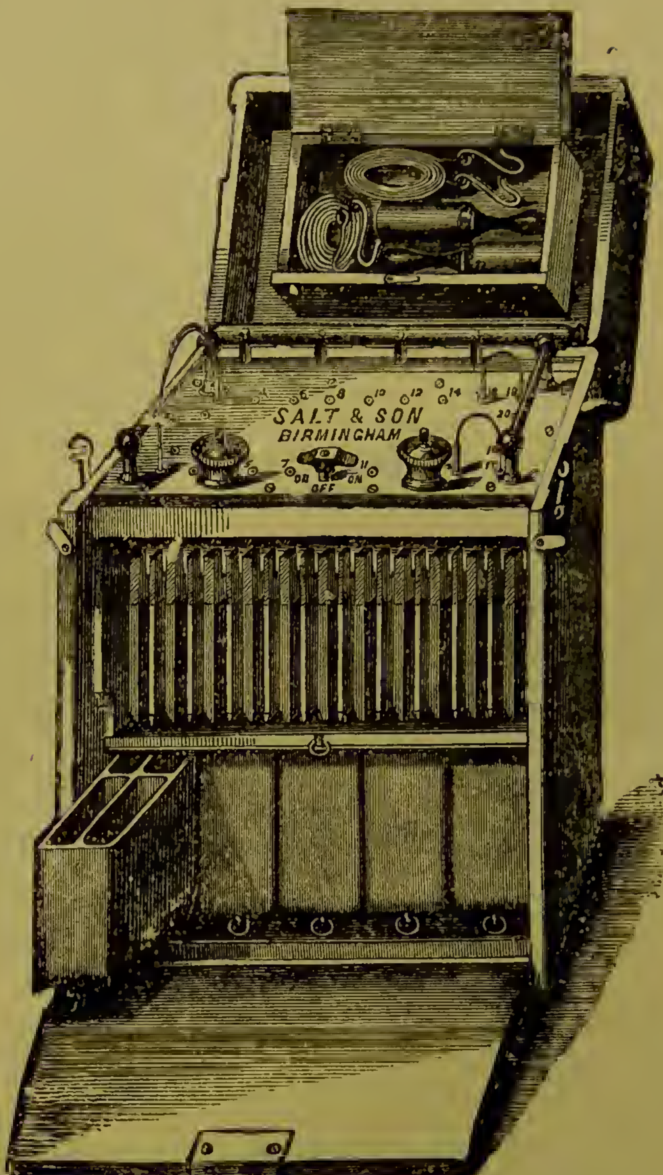
FIG. 45.



Stöhrer's 20 celled zinc-carbon portable battery, size, 10 inches long, 6 wide, 11 deep. The plates are immersed into the acid by raising the transverse bar, the ends of which are seen at each end of the battery. The sledge collector carries the binding screws for the rheophores, and a barrel commutator.

Stöhrer's 30 celled hospital battery, is 25 inches long, 9 wide, $11\frac{1}{2}$ deep, and is constructed upon the same principles as the portable battery.

Fig. 46.



Salt's battery of 20 zinc carbon elements. The element-board carries a pin and hole collector; two binding screws for rheophores and a commutator-interruptor.

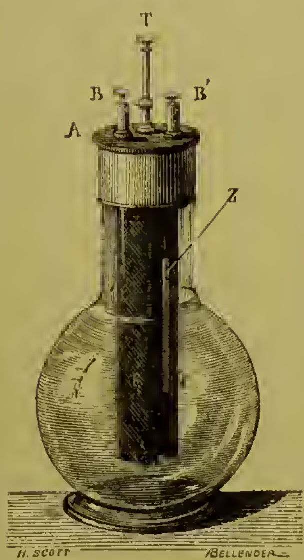
When not in use, a board lined with india-rubber prevents any spilling of the acid. The vulcanite cells as shown in the figure can be drawn out individually for replenishing.

Size: length, 11 inches; breadth, $6\frac{3}{4}$; depth, 13.

Weight: 24 pounds.

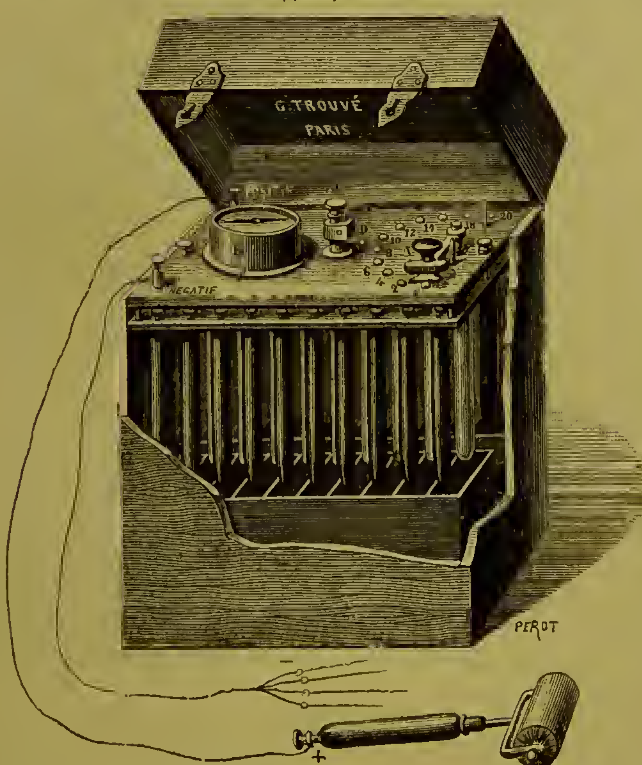
The 30 celled battery is 5 inches longer.

Fig. 47.



The Grenet element.—A plate of zinc, Z, between two carbons, C, C, dips into a solution of bichromate of potash in sulphuric acid, 1 part, and water 10—20 parts. A; valcanite plate bearing the binding screws, B, B' for connection. By means of the rod T, the zinc is withdrawn from the liquid when che cell is not in use.

Fig. 48.



Trouvé's battery for electrolysis.

It consists of 20 pairs of zinc carbon taken by twos, by means of a dial collector A. B, galvanometer; C, D, arrangement for the gradual immersion of the plates.

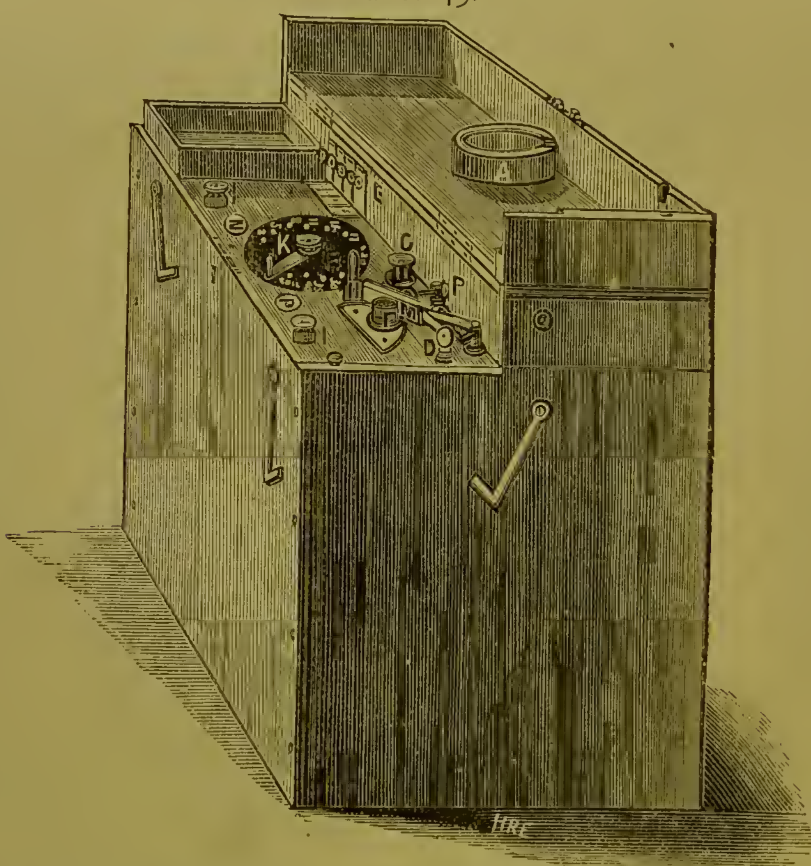
COMBINED BATTERIES.

Combined batteries consist of a faradic and a galvanic apparatus in the same case. Their advantages are that they form a more compact whole than two independent batteries, and that both currents may (at least in some of them) be sent through the rheophores without changing the points of attachment.

Their drawbacks are, first, that they are necessarily rather heavy, both apparatus have to be carried about even when only one is required; second, that they are somewhat complicated and hence liable to accidents; and lastly that when one part requires repair the whole is thrown out of use.

These considerations have led me to propose a modification in their construction which would obviate the inconveniences just mentioned. An ordinary galvanic battery has its element board fitted with a current reverser and alternator; and faradic apparatus lodged in a compartment or drawer in such a way as to be easily removed and used by itself, when required. For instance

Fig. 49.



Combined Battery designed by Dr. Tibbits. The elements used are Leclanchés, and the details of the construction are mainly those of the separate batteries described above.

Size of 40 celled combined batteries: length 13; breadth 8; depth 11½.

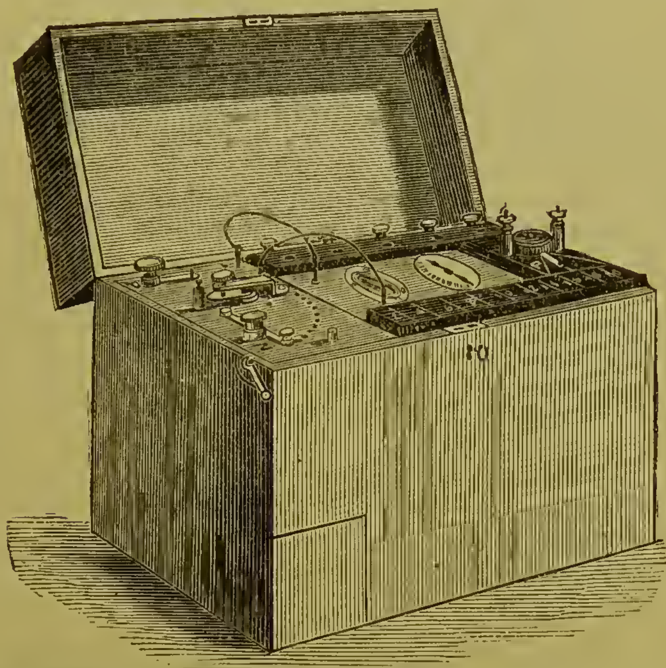
Weight: 43 pounds.

the apparatus (fig. 56) can easily be so adapted to the battery (fig. 41). In this way a "combined-separable" battery is obtained.

A. Batteries where both currents can be sent alternately through the rheophores without changing their place of attachment. Stöhrer's combined battery belongs to this category.

B. Batteries where the rheophores have separate points of attachment.

FIG. 50.



Mayer and Meltzer's combined battery.—The faradic apparatus is the same as that described elsewhere. The galvanic battery consists of 20 or 30 zinc carbon pairs. The vulcanite cells are lifted up, in sets of four, by means of rods, the tops of which are seen at the back of the element-board. The latter caries a sledge collector, with commutator, and a galvanoscope. The induced current is fed by 4 or more elements of the galvanic battery, which are connected with it by conducting cords as shown in the figure.

GALVANO-FARADIC APPARATUS.

THE general principles followed in the construction of induction machines have already been explained in Chapter I. They will be found pretty fully illustrated in the following drawings of the chief types of faradic apparatus. It would be an invidious as well as an impossible task to decide as to which deserves preference. Each possesses qualities of its own, and has its own drawbacks. Where portability is not an essential, an apparatus such as in figs. 51, 52, 69, is to be preferred. Where on the contrary portability is desirable, Gaiffe's and Trouvé's apparatus (figs. 55 to 59, and 64,) recommend themselves, as they do not contain any fluid liable to be spilt, and are of such a shape as to adapt them to the pocket. The adaptation of Leclanchés to faradic apparatus, is in some respects an improvement upon the use of single fluid cells, though open to

the objection of not being very constant nor easily recharged when exhausted. The most familiar faradic battery is probably Stöhrer's. Dr. Tibbit's instrument is mainly a Stöhrer in which Leclanchés are substituted for the zinc-carbon elements (fig. 55). Fig. 64 represents a very portable arrangement.

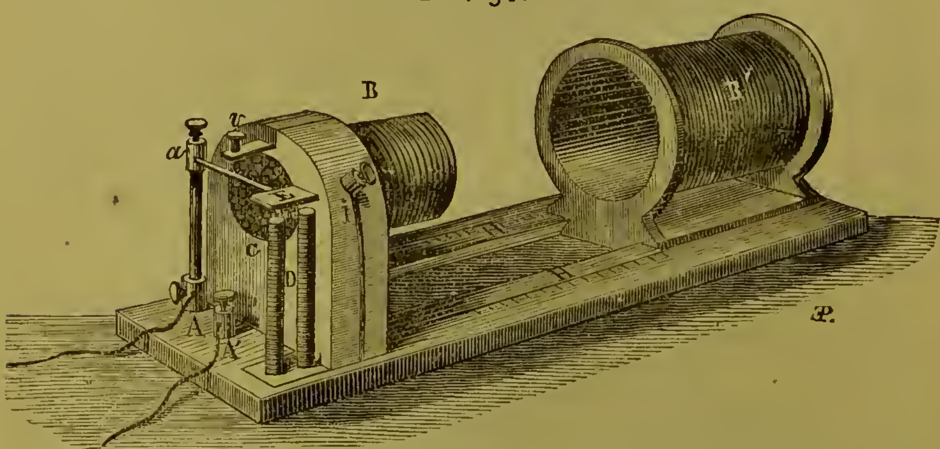
The experience I have had of Dr. Tripier's instrument made by Gaiffe (fig. 56) has been most favourable. Trouvé's interruptor (fig. 58) is very ingenious and well spoken of.

Defective action of a faradic apparatus may be due to several causes, having their seat in the various parts of the instrument, and is readily evidenced by the enfeebled vibration of the hammer.

The cells may be exhausted; and require cleaning and recharging. Some of the connections may be broken or oxidised. Some of the turns in the coil may be imperfectly insulated. But the most frequent part at fault is the interruptor. Sometimes a little manipulation of the screws which regulate its action is sufficient; or it is necessary to clean the platinum disk carried by the hammer (H fig. 3) at the point where it comes into contact with the screw (sc.) and the tip of the screw itself. The reason for this is plain: oxide collects at this spot, and offers a relatively considerable resistance to the passage of the battery current. This oxide is due to the chemical action of the battery current of itself and of the break extra-current (spark) through the metallic surfaces, in presence of air. Careful scraping with a pen-knife, or scouring with fine emery paper, readily removes the oxide.

The first two illustrations show the non-portable sledge apparatus, one with the original Neef's hammer, the other with Gaiffe's improved interruptor.

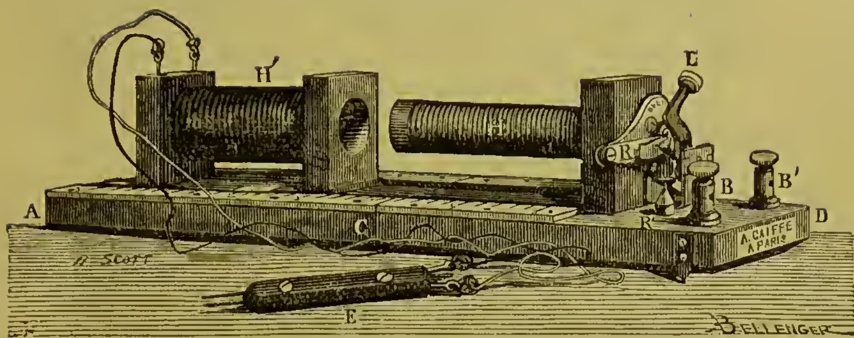
Fig. 51.



Siemens and Halske's apparatus, AA' binding screws for the battery rheophores.
B. B', primary and secondary coils.
H, H, graduated scale along which B' can slide
C, core of soft iron.
a, v, D, E, Neef's hammer.

M. Gaiffe constructs a similar apparatus with 3 secondary coils, (the wires of which are of 66 metres, 1·4 mm.; 198m, 0·7 mm.; 600m, 0·225 mm. in length and thickness respectively); and with his graduation hammer, giving from 5 to 50 interruptions per second.

FIG. 52.



Du Bois-Reymond's sledge faradic apparatus, with Gaiffe's improved lever and hammer. The board A D is jointed at C for the sake of convenience.

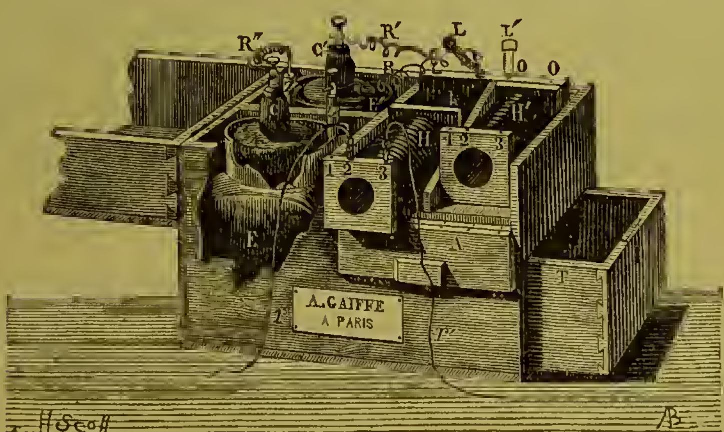
BB′ are the connecting screws for the battery.

L, lever for graduating the interruptions.

R hammer; R′, pin for making slow interruptions.

Portable induction apparatus with battery of Leclanchés.

FIG. 53.



Hospital faradic apparatus. Primary and secondary coils of the same length and size as those in the former apparatus.

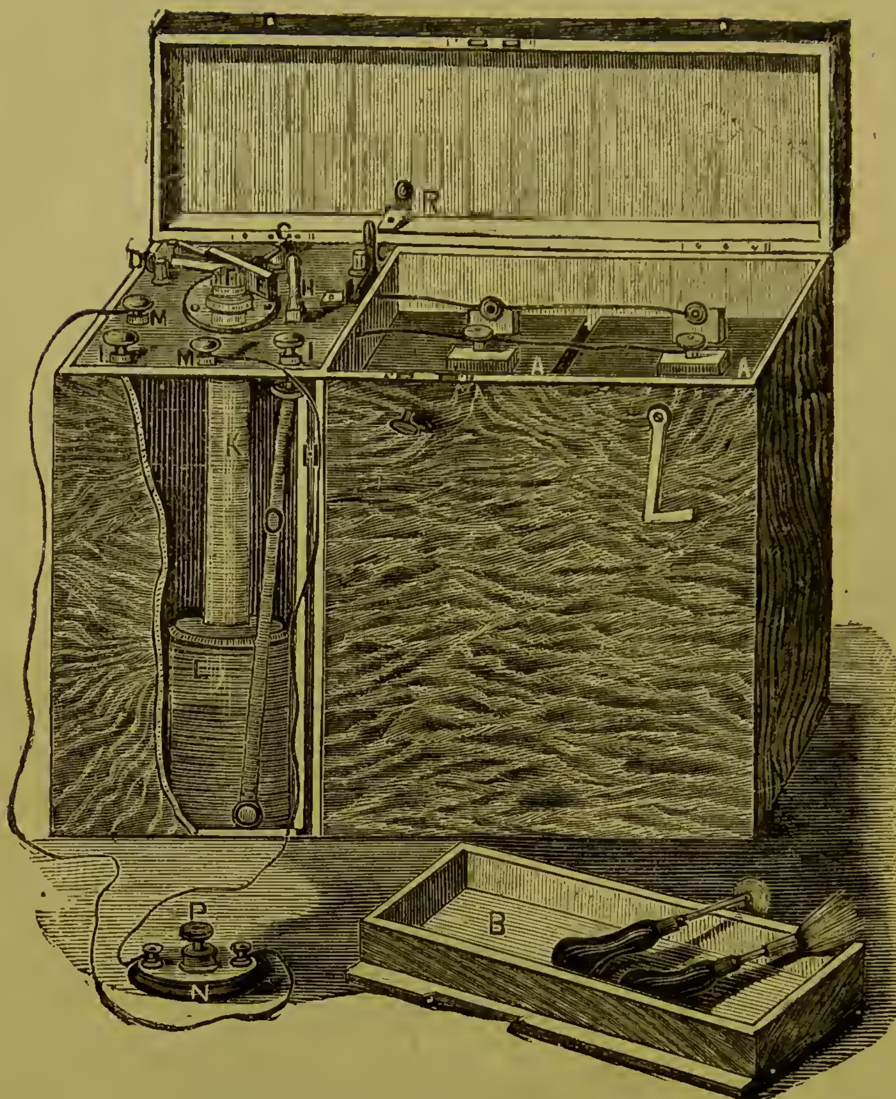
EE′. Two Leclanché elements, connected by RR′ with the coil and hammer.

L. Lever.

h. Primary coil; H H′ secondary coils, the second in a compartment for the one not in use.

O, O. Holes for the rheophores when the extra-current is wanted; for the pedal rheotome; and for an external battery, if required.

FIG. 54.



Faradic apparatus, designed by Dr. Tibbits. Size: length, 13 inches; breadth, $4\frac{1}{2}$ inches; depth, 10 inches; weight, 16 pounds.

AA. Two large Leclanché cells, united in multiple arc, and exposed by the removal of B, a drawer for accessories.

C. Key for closing the circuit between the cells and the primary coils—the circuit is automatically broken by the guard R, when the lid is shut.

D. Screw regulating the intermittences of the hammer E.

F. Soft iron core protruding from the primary coil K.

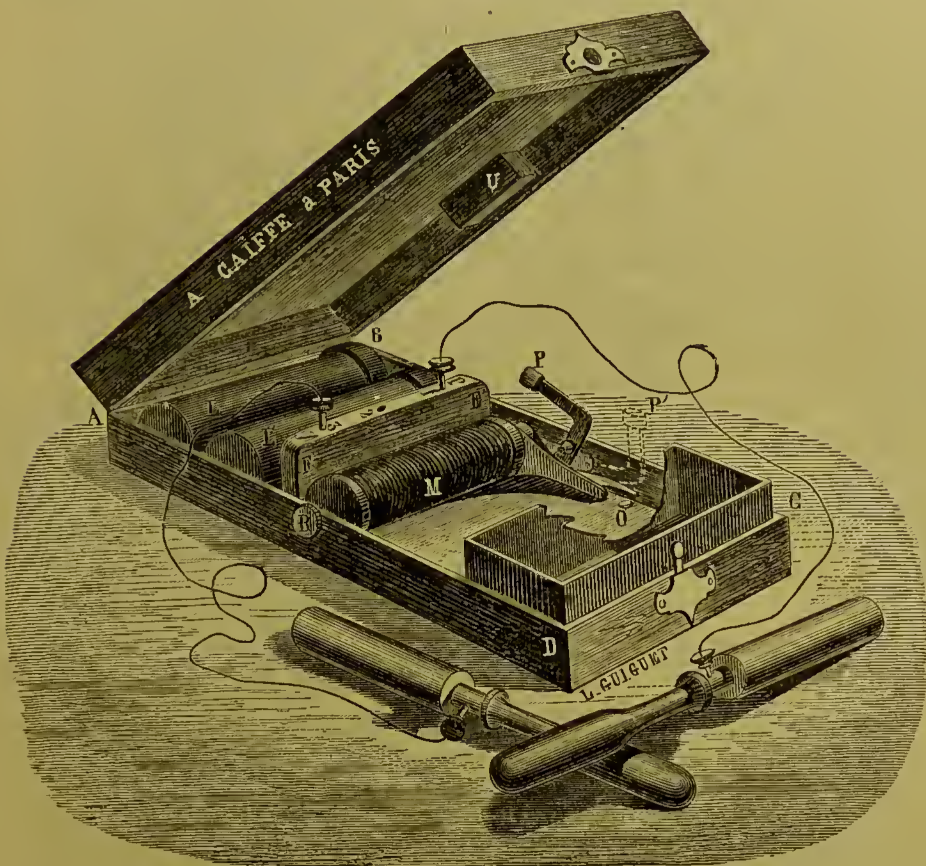
G. Screw between which and F the hammer vibrates.

H. Rod for elevating the secondary coil, L, which is kept in any position by the spring O. The drawing represents the secondary entirely withdrawn from the influence of the primary—at least practically so for therapeutical purposes. The current strength will depend upon the amount of the secondary made to enclose the primary; this evidently is measured by the protrusion of H, which is accordingly graduated.

M, M. Binding screws for attaching Duchenne's pedal rheotome N. Slow interruptions are made by pressing upon the spring P with the foot.

In the following the battery consists of chloride of silver elements.

FIG. 55.



Gaiffe's pocket faradic apparatus.

A, B, C, D. Box containing the apparatus.

L, L′. Two chloride of silver cells.

M. The primary and secondary coils.

R. Milled head for pulling out the graduating tube.

P. Lever which sets the apparatus into action and graduates the rapidity of intermittences.

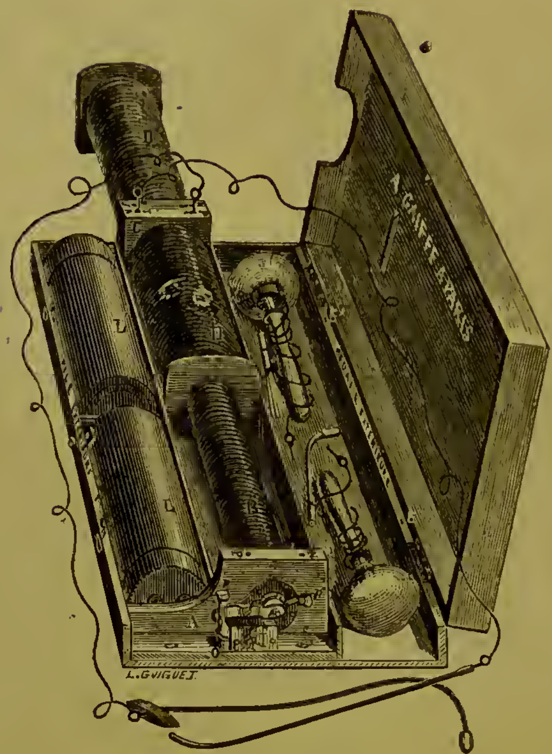
O. Metallic pin for producing slow interruptions. For this purpose the lever in P′ is pressed down with the finger so as to bring it into contact with O.

EF. Block bearing the holes for fixing the rheophores.

P, N. Indicate the positive and negative poles. The pins when in 1 and 3 transmit the current of the whole length of the coil; when in 1 and 2, two thirds; when in 2 and 3 one third of the length.

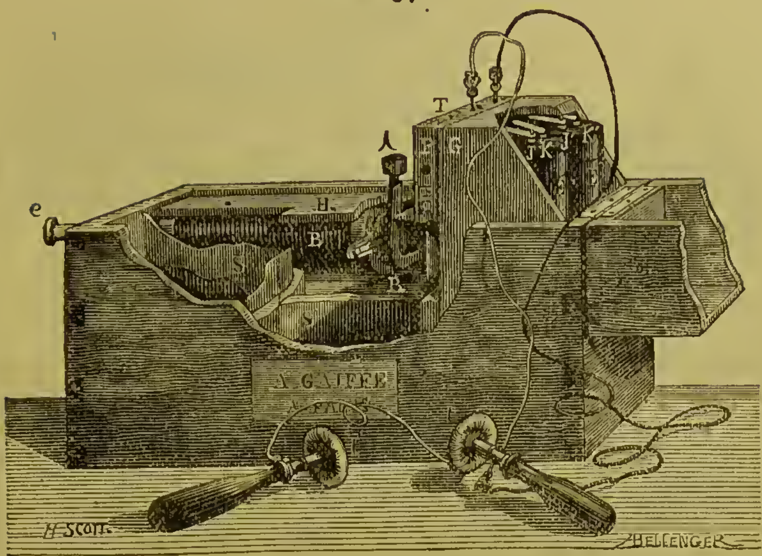
Mr. Hawksley (of 300 Oxford Street) is prepared to recharge the elements of this and the following batteries when exhausted.

FIG. 56.



Gaiffe's portable faradic apparatus, with two induced coils.
Inducting coil; length, 25 metres; diameter 0 mm, 7.
Thick secondary; ,, 75 ,, ,, 0 mm, 7.
Thin secondary; ,, 450 ,, ,, 0 mm, 175.
LL. Two chloride of silver cells.
B. Primary coil.
H, H′. Secondary coils, reversable according to the one required.
C. Block for fixing the reophores.
P, P′. Lever for regulating the interruptions, carried on the block I.
O. Button for making the slow interruptions with the finger.
E, E′. Holes for connecting the interrupting pedal; D, D′, for an external battery, when required.
Size: length, 10 inches; width, 6 inches; height, 2½ inches; weight 3½ pounds.

FIG. 57.



Hospital faradic battery.

EE. Two chloride of silver cells, fixed by means of springs J, K; J'K', which connect their respective poles; and contained in a closed compartment G.

T. Block carrying the holes for fixing the rheophores t, t'; and those for connecting the apparatus with an external battery, of which the positive pole is connected at P, the negative at a corresponding point, on the other side.

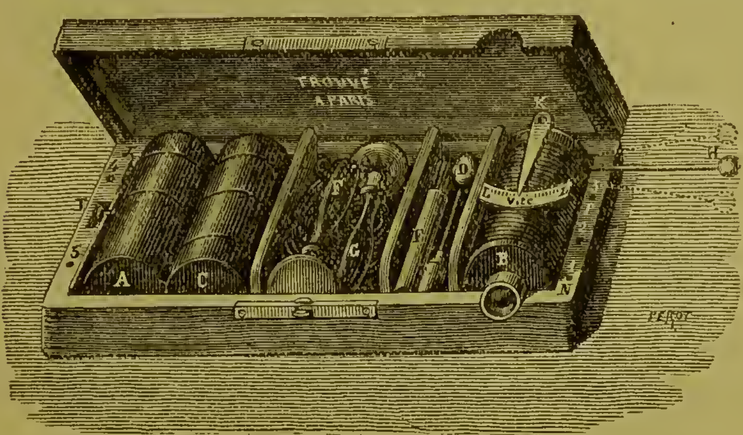
e. Graduating tube.

S, S'. Compartments for the dry and moist electrodes respectively.

The coils, B, are protected by the board H, and the interruptor lodged in the space R, are similar to those described under the pocket battery.

The next two are fed by sulphate of mercury cells.

FIG. 58.



Trouvé's faradic battery.

A. Hermetical cell. B. Coil. C. Case containing bisulphate of mercury.

D, E, F, G. Electrodes.

H. Prolongation of the interruptor for modifying the rapidity of the vibrations.

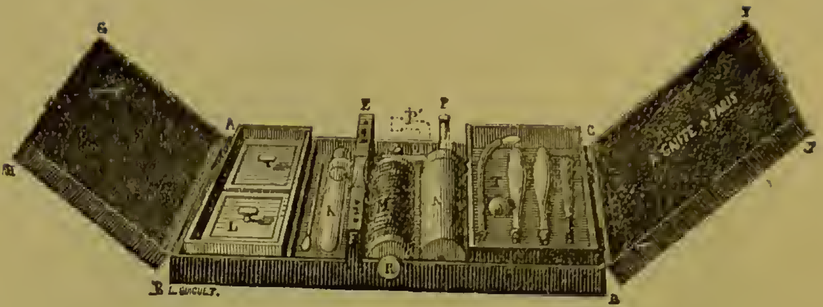
K. Hand indicating upon L the number of vibrations.

When the rheophores are fixed to 1 and 2 the extra-current (primary) is obtained; when in 2 and 3, the induced (secondary) when in 1 and 3 both.

N, P. Negative and positive poles.

4, 5. Holes for receiving the rheophores of an external battery when desired.

FIG. 59.

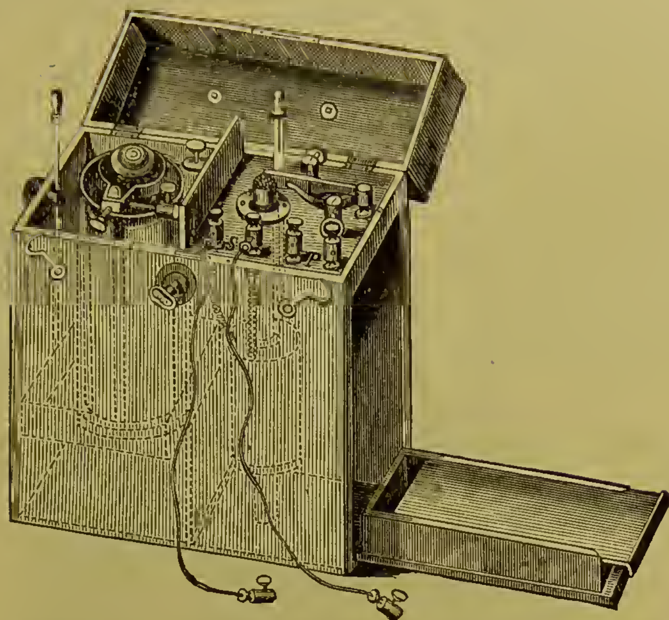


Gaiffe's pocket faradic apparatus. M, coils. R, graduating tube. T, N, electrodes. P, hammer. E, block for the attachment of rheophores. The battery L consists of two cells formed of vulcanite troughs, a plate of carbon is let in at the bottom, and the zinc is in the shape of a moveable cover. In order to charge the battery, a spoonful of the mercury salt contained in the bottle K is put into each cell, with a little water. Once charged it works for about one hour.

FIG. 60.

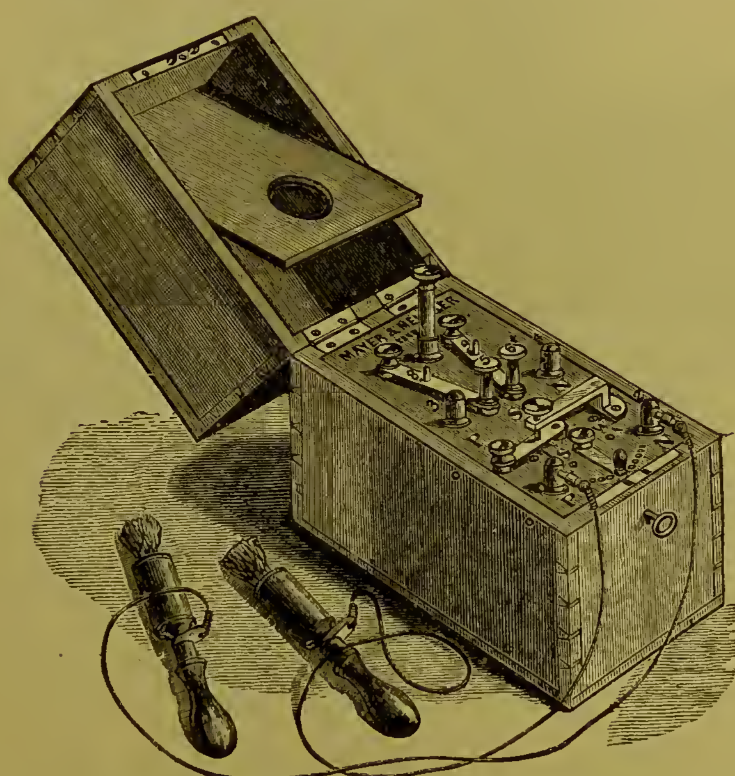
Stöhrer's double celled induction apparatus. Size: 14 inches long, 5 wide, 10½ deep. The cells consist of carbon-zinc elements; the carbon stands in the centre and is made in the form of a cylinder. The zinc surrounds the carbon and is bathed in dilute sulphuric acid. The carbon cylinder contains sand moistened with chromic acid.—To the right are seen the binding screws for the primary and secondary currents, the rods for graduating these currents, and the interrupting apparatus.

FIG. 61.



Stöhrer's single celled induction apparatus. Size: 10½ inches long, 5 wide, 10½ deep.

FIG. 62.

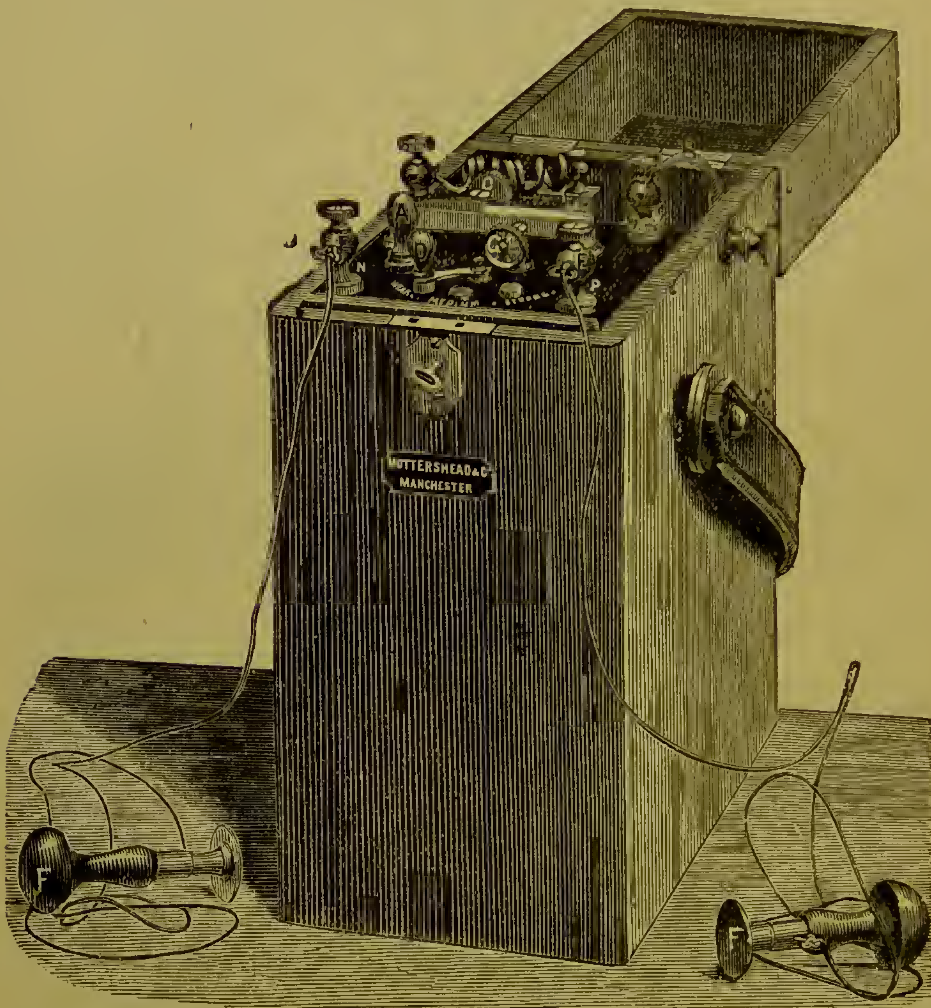


Mayer and Meltzer's small faradic apparatus.

The cell is a Grenet which is put into action by pressing down the rod 7. The graduation of the current is effected by means of a dial arrangement. An index serves to turn on the primary or secondary current at will, without changing the attachment of the rheophores.

Size: length, 6 inches; breadth, 4½ inches; height, 4½ inches. Weight: 3 pounds.

FIG. 63.



Mottershead's faradic apparatus. D handle for the coarse adjustment of the current strength, by means of the studs "weak," "medium," "strong."

A. Rod for the fine adjustment.

G, C. Screws for regulating the number of intermittences.

The primary and secondary coils are continuous, and the make secondary current passes through the battery. (See on this point the controversy in "*Lancet*," July, 1877).

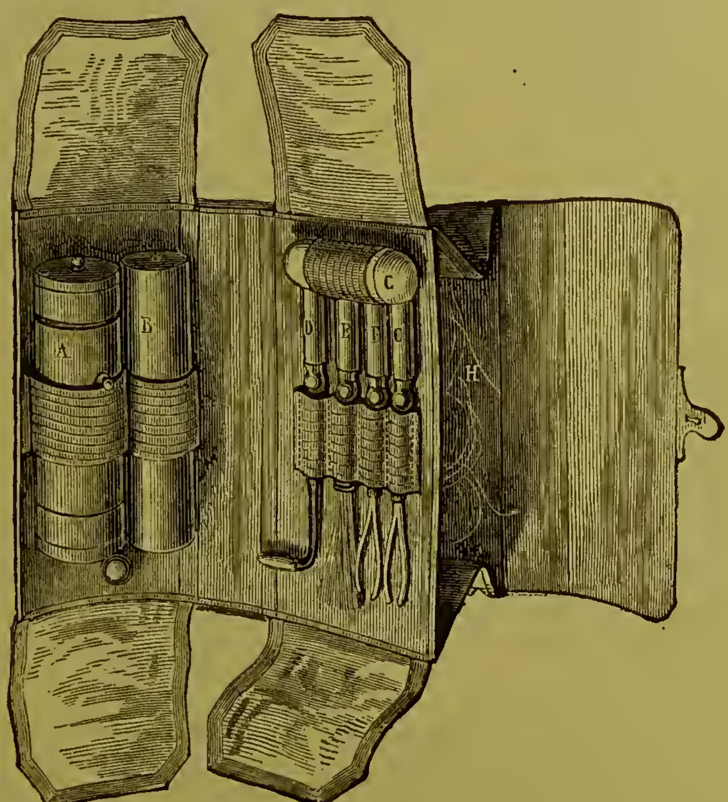
Size: length, 5 inches; breadth, 8½; depth, 10½; weight, 8 pounds.

Amalgamation.

It is advantageous to the owner of any of the last mentioned apparatus to be alive to the necessity of having his zincs always thoroughly amalgamated. Unless a piece of zinc be perfectly pure and of perfectly homogeneous consistence it acts, when plunged into dilute acid, as two or more metals and "secondary actions" are set up within the cell. That is to say the points where the zinc is harder, or contains iron or arsenic (as all commercial zinc does) act as negative electrodes to points where the metal is softer and currents are set up between such points through the liquid and the plate, and thus the metal is gradually eaten away. "Amalgamation" obviates this serious drawback by giving to the surface of the metal a homogenous consistency. The modus operandi is as follows: wash the zinc with dilute sulphuric acid (1 : 4) then drop a little mercury upon it, over a plate, and rub in the adhering drops until the whole surface is uniformly shining and smooth. A hissing noise heard when the plates are immersed in the acid is a sure sign that the zincs require re-amalgamation.

The illustrations here appended (figs. 64-67) show a pocket faradic apparatus, due to the ingenuity of M. Trouvé.

Fig. 64.



Trouvé's pocket faradic apparatus.
Its component parts are fitted into an ordinary surgical pocket case, fig. 64.

Fig. 65.

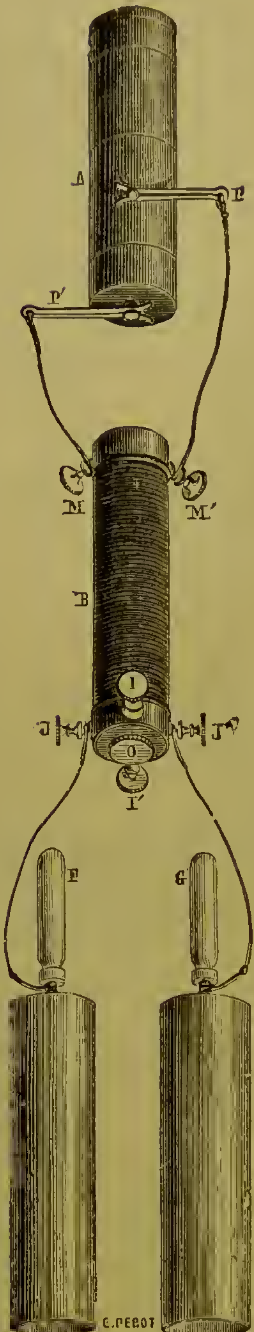


Fig. 66.

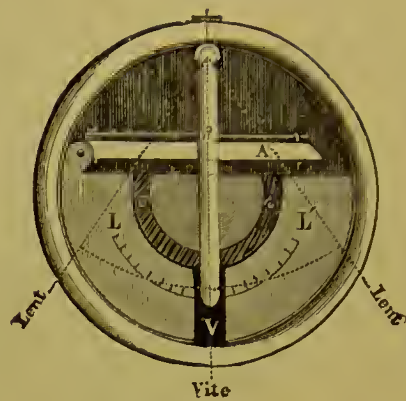
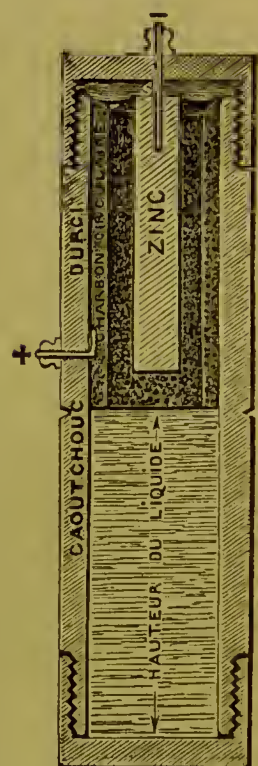


Fig. 67.



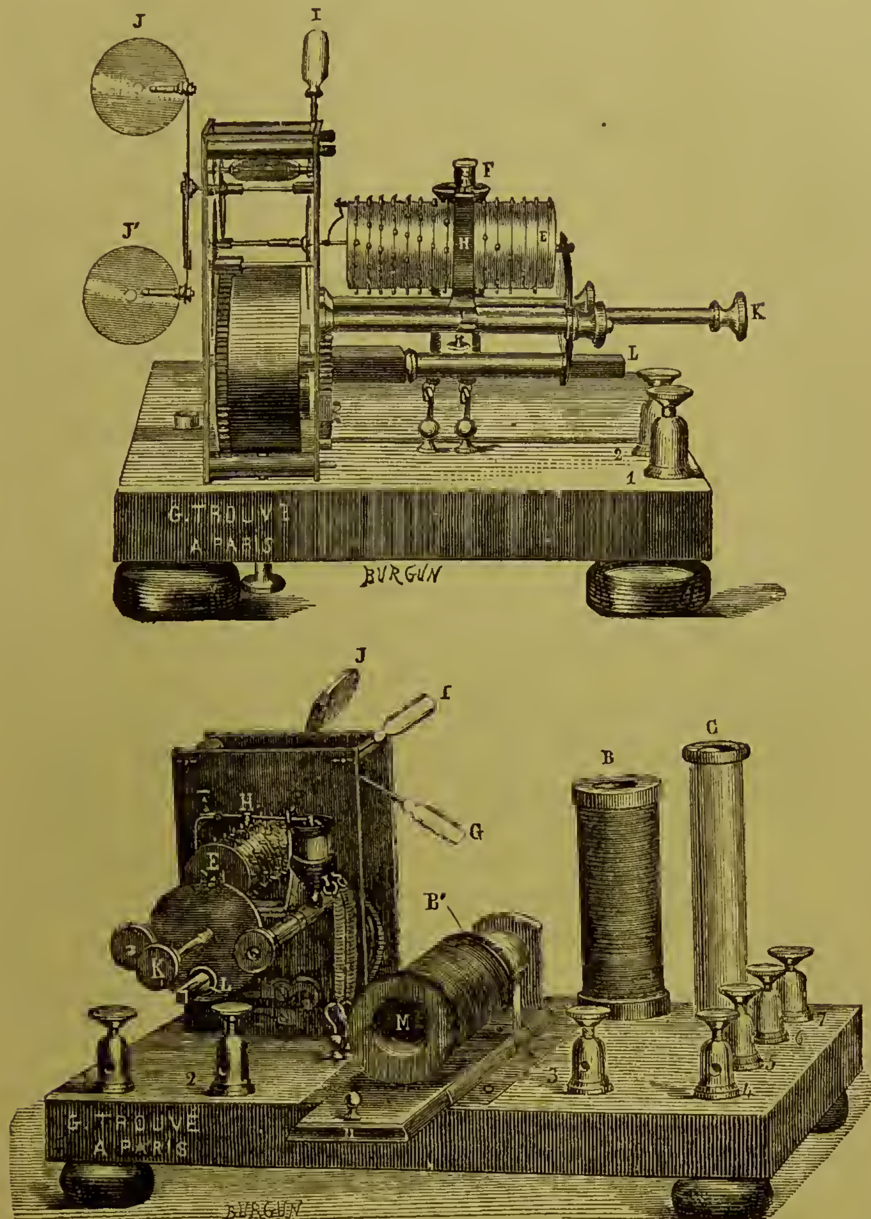
The cell A is shown in section, in fig. 67. The coil B is fitted with an ingenious current-breaker, represented (enlarged) in fig. 66. When the lever, as depicted, rests on V, the interruptions are rapid ; when pushed towards L, or L′, the interruptions become slower. The case contains sponge holders, F, G, a pointed electrode, and a metallic brush.

Fig. 65 represents the various parts connected for action.

The references are the same as above.

APPARATUS for producing numbered and measured interruptions in an electrical current.

FIGS. 68 AND 69.



This apparatus has been constructed for Dr. Onimus by Trouvé, of Paris.

The first figure shows the interrupting part by itself; the second shows in addition the inductorium.

Binding screws 1, 2, are for attaching the wires for obtaining the interrupted galvanic current. 3, 4, for the wires of the battery for the faradic current. 4, 5, for the rheophores when the primary or extra-current is required; 6, 7, for the secondary; 5, 7, for both primary and secondary.

The interruptor consists of a cylinder E, made up of 20 disks carrying from 1 to

20 pins, in regular progression. A clock-work arrangement causes the cylinder to revolve.

A fly wheel J, regulates the number of revolutions of the cylinder (from 1 to 4 a second).

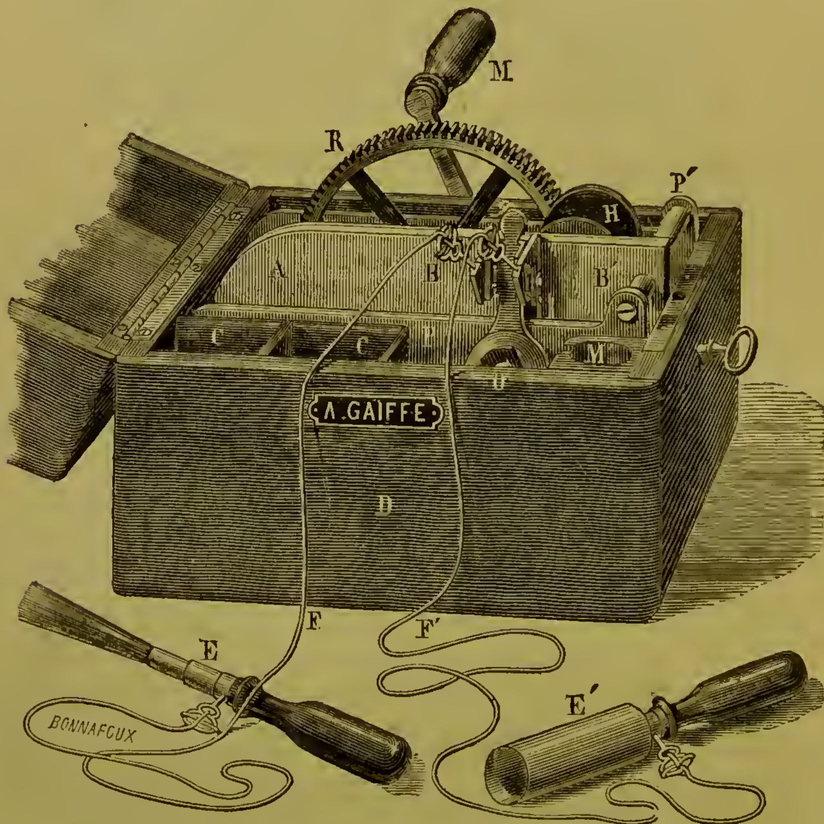
A lever H, with mercury cup arrangement, is made to assume any position along the cylinder by means of the rod K. This lever every time it comes into contact with a pin, breaks the current. In this way from 1 to 80 interruptions a second are obtainable.

M primary coil, C metallic tube to regulate the extra-current; B, B′, secondary coils of different length and thickness; D sledge for graduating the secondary currents; L is for winding up the clockwork. I and G, represent the lever for starting and stopping the clockwork, in its respective positions.

An ingenious contrivance not shown in the figure is added to the interruptor, by means of which the successive passages of the battery current are made of strictly equal duration.

MAGNETO FARADIC APPARATUS.

Fig. 70.



Clarke's magneto-faradic apparatus, modified by Gaiffe so as to send the currents in the same direction, and allow of a more accurate regulation of the current strength.

A B B′. Horseshoe magnet.

H. Soft iron armature revolving in front of the magnet, and carrying 2 coils one of which only is visible.

M, R. Wheel and handle for making the armature revolve.

G. Regulator, articulated at O, which according as it is pushed towards B or B′, increases or diminishes the strength of the current.

P P′. Supports of the apparatus.

M. Receptacle for the handle.

C, C. Compartments for the electrodes.

A magneto-faradic machine consists mainly of an armature of soft iron revolving in front of the poles of a horseshoe magnet, and a pair of coils of insulated copper wire. These coils are fixed in Clarke's machine to the armature with which they revolve; in Duchenne's to the magnet itself.

In the first case electromotive force is induced in the coils by the successive magnetisation and demagnetisation of the armature due to the influence of the magnet in front of which it revolves.

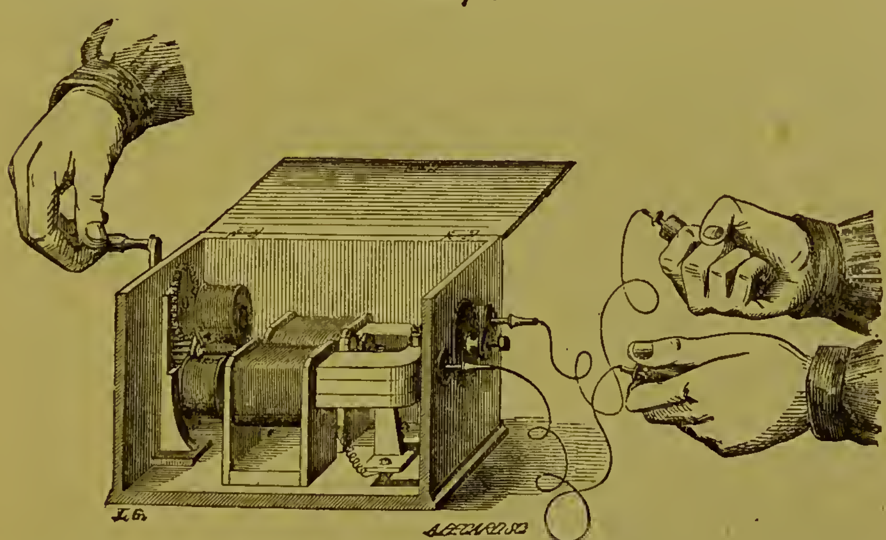
In the second case induction is produced by the variations in the magnet itself due to influence of the armature.

In both these forms only the currents arising during the passage of the armature *from* the magnet are collected for use.

M. Gaiffe has improved the older forms of magneto-faradic machines inasmuch as he has combined the two systems and provided his apparatus with two pairs of coils, one fixed to the armature, the other to the coil. This increases the power of the instrument whilst it allows of diminishing its size considerably. He has in addition fixed a commutator to the axis of the armature, which combines the currents of the two pairs of coils and transmits them all in the same direction to the positive pole of the instrument.

The fact of a magneto-faradic apparatus giving a uni-direction current is a matter of considerable importance. For unlike the galvano-faradic make and break currents of which, with high resistances, the second has no appreciable physiological, and neither any chemical action, the to and fro magneto-currents are physiologically equivalent; and what is more they both have a sensible chemical effect.

FIG. 71.



Gaiffe's improved magneto-faradic apparatus. It is provided with a mechanism by means of which the current from the 4 coils flows always in the same direction.

This machine is provided, if desired, with two sets of coils: one of fine wire, the other of thick wire for producing currents of high or low tension as required. The current strength is graduated by an adjustment screw seen between the poles.

This screw modifies the distance between the magnet and armature; and this is indicated outside the box by a hand revolving upon a dial divided in degrees.

ACCESSORIES,

Current Graduation.

The first condition to be fulfilled by a medical battery is to be furnished with the means of graduating the current strength so as to adapt it to the requirements of every case. Looking at Ohm's formula $C = \frac{E}{R}$ it is evident that C can be modified, 1st, by making E, that is, the number of elements used, larger or smaller; 2nd, by making R, that is, the resistance in circuit, larger and smaller. There is yet a third method of graduating current-strength, that of establishing a derived current with a resistance variable at will.

A. The latter method has been adopted by many electro-therapeutists after Brenner's example. Its theory is explained under the head of "Derived Currents." It allows of very fine graduation, but is very wasteful, and applicable only when a battery of Daniells is used. It is, as far as I know, never used in this country. These reasons, and the fact that better results still are obtained by the use of a rheostat and absolute galvanometer in the primitive circuit, allow us to dismiss it without further notice.

B. In order to graduate the current by modifying the resistance in circuit, a liquid or wire rheostat is used, capable of interposing such resistances as to reduce the current to the minimum strength ever required; by gradually diminishing this resistance, the strength of the current is gradually increased. For medical purposes wire rheostats, or resistance coils, are unpracticable owing to their expensiveness. Nor do they offer any marked advantage, since rapidity and fineness of graduation are requisite, rather than the interposition of *known* resistances. Liquid rheostats are therefore to be preferred. They may consist simply of tubes filled with pure water, or dilute solution of salts, with a rod working like a piston as explained elsewhere. They need no graduation, the only datum requisite for intercalating the necessary amount of resistance being the effect produced upon the strength of the current as indicated by the galvanometer.

The advantages of the rheostat as current regulator are: First, its simplicity and cheapness. It is obvious that the more or less complicated mechanism and multitude of wires necessitated by collectors being done away with, the battery will be less expensive and less likely to be out of order.

Second, the facility and fineness of graduation. Graduating the current strength by taking cells by twos or fives, as is often done, is obviously a far rougher proceeding than by the gradual motion of a piston.

Third, the imparting to the current the qualities of "high tension." Upon this point I refer the reader to what has been already said under the head of "Constancy of the Current."

Practically, there is an objection to the use of the rheostat: it is not to be had from most instrument makers, and much experience is yet wanted in order to give it the utmost perfection of shape and

convenience. I am glad to say, however, that both Messrs. Coxeter and Son and Messrs. Mayer and Meltzer, are now engaged in constructing batteries in which rheostats replace the usual collector.*

One word of caution is necessary: before applying the current to the patient care must be taken that the full resistance be intercalated; otherwise an unpleasant or even dangerous shock would be given. The possibility of disregarding this rule has been held to be an objection to the use of the rheostat: but precisely the same might be said of any current regulator. In fact I have known the same accident to occur with a dial collector, as happened to Duchenne with his water rheostat.

C. The third method of regulating the current strength is the including in the circuit the number of cells requisite to bring the current up to the requisite strength. Several contrivances have been devised. The general construction of all collectors, however, consists mainly of wires connecting the cells of which the battery is composed, to metallic pieces on the element board. These metallic pieces are insulated, but can be brought into relation with the termination of the reophore by means of plugs, springs, etc.

Two essential conditions must be fulfilled by any collector intended for a practitioner's battery:

1. It must proceed by small increments in the number of cells.

2. It must not break the current with every change of current-strength. This is done by adopting precautions mentioned further on, when the various kinds of collectors are described.

With regard to the first condition it may be laid down as a rule, that no collector should be made which does not allow taking cells by twos (if Leclanchés) or threes (if Daniells) *at most*. After the first 15 or 20, the increments may be larger. Fig. 72 represents a most rational arrangement. The cells are taken one at a time up to five; then two, up to 15; then three etc.†

The Plug Collector.

This is the simplest, least likely to get out of order, but also the least convenient to work, of the various collectors. Several kinds of it exist, which will be found illustrated among the various batteries depicted in this book.

Brenner strongly advocated such a collector, much resembling the ordinary plug system of resistance coils in its external appear-

* Since the above was written Mr. Coxeter has introduced a new patent rheostat which seems to fulfil the conditions of medical practice, viz., lightness, compactness and facility of handling, together with efficiency and cheapness.

I may add here that it may be found convenient to combine the two methods, and have a collector taking the cells by fives, tens, etc., together with a rheostat for the finer adjustment of current-strength.

† Some time ago I happened to come across a battery purporting to have been "examined and approved" by "Harry Lobb." It consisted of Leclanchés taken five at a time, by means of a pin and hole collector. A more ridiculously inadequate arrangement for current graduation could hardly be imagined.

ance. But I am not aware that it has been adopted by any other electrician, and therefore shall only mention it here.

In some batteries, as in Trouvé's small portable apparatus, Beetz's and Coxeter's peroxide of manganese batteries, the rheophores are fixed to the cells themselves.

In others, again, the wires from the cells are connected to metallic pieces, into which a pin or plug attached to the rheophore can be fixed. This arrangement is adopted in Gaiffe's cheap peroxide of iron battery. Another modification of the pin and hole collector is adopted in Salt's battery.

Whenever such a collector is used it is absolutely necessary to adopt some means allowing of changing the current strength during an application, without sending a shock through the patient whenever a plug is moved. For this purpose a double rheophore, that is to say a rheophore bifurcated at one extremity should be used, with each of its branches carrying a plug. The plug actually in use should never be removed before the second has been fixed to the hole above or below, as the case may be. A perfectly smooth graduation of the current is thus obtained.

The Sledge Collector.

This collector is adopted in Stöhrer's and Mayer and Meltzer's zinc carbon batteries. A sledge running between two groves carries on its inferior surface two springs which come successively into contact with metallic pieces arranged into two rows. To these pieces the wires from the cells are attached. The sledge carries on its upper surface two binding screws, connected with the springs for the rheophores, and a commutator. The cells are thus taken two by two; but by a simple arrangement, which consists in making one of the springs movable, Baur has improved the sledge, and made it possible to take the elements one by one.

The springs are made long enough to avoid breaks in the current when the sledge is moved along, exactly as in the dial collector.

The objection to the sledge collector is, that when the battery contains a large number of cells, it assumes an inordinate length.

The Dial Collector.

This is the most generally adopted form of collector. In the centre stands a pivot upon which revolves a metallic spring, like the hand of a watch. The free extremity of the spring comes successively into contact with a number of metallic pieces, screw heads or studs, arranged in a circle around the central pivot. The negative pole of the first cell is directly connected with one of the binding screws to which the rheophores are attached. The positive pole of each successive cell, (or 2nd, 3rd, etc. cell) is connected in order with the metallic pieces of the dial, and through the spring and pivot to the second binding screw. The dial-studs are numbered so as to indicate the number of cells included in the circuit. The free extremity of the spring is made broad enough to come into

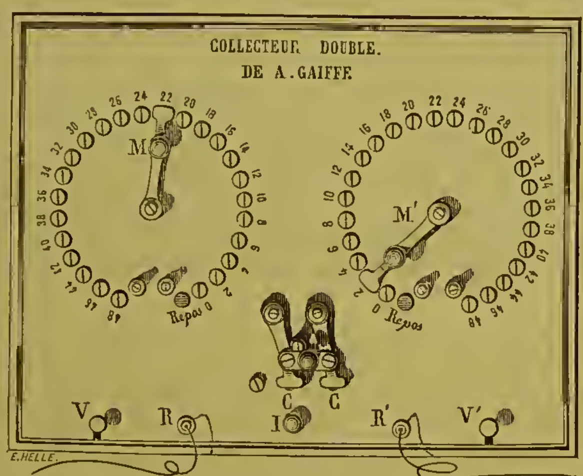
contact with the next stud before leaving the previous one, so as to avoid breaking the current every time it is moved.*

Fig. 72.

Dial collector arranged for starting from either end of the battery.

The obvious disadvantage of the dial collector is that the first few cells of the battery become exhausted long before the last which are more rarely used. Various contrivances have been devised to remedy this drawback. Thus, as will be seen in Mottershead's apparatus, shunts are provided by which 3 or 4 sections of the battery can be called into play separately. Dr. Tibbits' arrangement allows of beginning at either end of the battery. But the most perfect contrivance of this kind is Gaiffe's double collector. Its advantages are: 1° that

Fig. 73.



The double collector consists of two dials, each with the same number of studs or screws, which correspond to the number of cells. The negative pole of the first cell is connected with O, the positive of the 48th with 48, and the wires connecting the second to the third, the fourth to the fifth cell, and so on, attached to the screws, marked 2, 4, etc. respectively. The screws in both dials having the same number are connected directly together by transverse wires.

M M′ are handles revolving upon the dials, and connected with the binding screws R and R′ respectively. It is evident then, that the number of cells included between M and M′ are thrown into action when the circuit is closed externally, and that the negative pole is on the side on which the handle rests upon the smaller number. When the two handles rest upon the same number, no cells are in circuit. Thus, in the figure, the cells in action would be 20 in number, from 3 to 22 inclusive. If the handle M′ were pushed on to 20, only two cells, 21 and 22 would be active; if pushed on to 42, 20 cells would be again included, but M′ would then be the positive pole. The current reverser C C′ is described elsewhere, and the interruptor I, is a simple knob on a spring, which is pressed down with the finger. V V′ are bolts for fastening the element board to the battery. Hinges not shown, fix it on the other side and allow of a free access to the interior of the battery.

* Great care must be taken *never* to leave the spring in contact with two contiguous studs, as it short-circuits the included cells and rapidly runs them out.

the cells can be used perfectly evenly throughout, as we can bring into action any one, two or more, of the whole number; 2° that it enables us rapidly to verify the state of the battery, and immediately pitch upon the disabled cell if such a one exists; 3° that it allows us of reversing the current, the electrodes being in situ, without sending a voltaic shock through the patient.

In Trouvé's arrangement the starting point is in the middle of

Fig. 74.

This figure represents an arrangement by which the two halves of a battery can be used independently. In the battery depicted, of 50 elements, it will be seen that the first 25 elements can be used by working with the left hand collector and pair of handles, the second 25 by working the right hand only. In reality there is only 1 central handle which acts as negative or positive pole according as to which half of the battery is used. When more than 25 elements are required, the two outside handles are employed, and the required number of cells made up between the two collectors. A glance at the arrangement of wires in the battery will explain better than a description the principle of the arrangement.

the battery, the two halves of which can thus be called into play separately.

Rheophores.

Nothing but actual experience can give an idea of the petty annoyances and loss of time inflicted by the use of bad rheophores. The stuff supplied by many instrument makers is perfectly useless. On the whole thin telegragh wire, that is copper wire encased in a sheath of india-rubber is to be preferred, on account both of its efficiency, and its cheapness and durability. I have been much pleased with Gaiffe's improved rheophores, consisting of 12 fine copper wires enclosed in a double sheath of india-rubber and silk. They are more springy than the telegragh wire, and less apt to become entangled. In any case it is convenient to have the positive and negative rheophores of different colour, or otherwise distinguishable.; a knot, or other mark at the two extremities of one of them

is sufficient to identify them at a glance without going each time through the process of disentangling.

The drawer of the battery should always contain a few spare yards of telegraph wire, besides the two pieces—each about four feet long—actually used as rheophores.

For many purposes it is necessary to have a double rheophore, that is one bifurcated so as to allow of two electrodes being attached simultaneously, as when it is desirable to diminish the local action of the negative pole; or act upon two points at the same time; or again as in electro-diagnosis, as will be mentioned further on. A double rheophore is readily manufactured from two pieces of telegraph wire, about two and four feet in length respectively. The larger piece is attached by one extremity to the battery, by the other to the middle point of the shorter, the two extremities of which carry the electrodes. The double rheophore mentioned with regard to the pin and hole collector may be made in this way, as well as the multiple rheophores used in electrolysis.

Connections.

Speaking of rheophores I must advert to a very important practical point, upon which too much stress cannot be laid. Many failures in electrisation are due to the imperfect contact of the wires with the pins, screws, etc. to which they are attached. It must be adopted as an invariable rule, that no connections are to be tolerated where a wire is simply tied to, or wound round, a piece of metal. The contact must be established either by a screw, or by soldering. The bungling manner in which some makers connect their rheophores is simply disgraceful. Whenever air is admitted between two surfaces of metal conveying an electrical current, oxides form, which oppose a strong resistance to electricity. In addition it frequently happens that loose connections produce interruptions, hence disagreeable shocks to the patient. It is of course necessary that where screws and plugs are used, the surfaces of metal should be clean to begin with. This is best secured by a preliminary rub with fine emery paper, a small provision of which ought to form part of every electro-therapeutist's fittings.

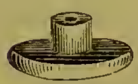
Electrodes.

For most purposes the *handles* should be 3-4 inches long, 1 inch in diameter, and hollowed out about their middle so as to be conveniently held both in one hand, between the first and second, and third and fourth fingers respectively. For purposes of labile applications to a large surface, much larger handles may be used with advantage.

The familiar copper cups and sponges ought decidedly to be excluded from the battery. They are both dirty and unsatisfactory. If sponges are to be used, either plated, or vulcanite, or wooden cups should be provided so as to avoid the formation of copper salts, which, besides imparting a repulsive green discoloration to the sponge, materially interfere with the conduction of the current.

Fig. 75.

Fig. 76.



Gaiffe's handle and carbon disk electrode.

Far superior, however, to any sponge-electrodes are the carbon electrodes, consisting of a carbon disk enclosed in a cover of flannel or washleather. Their advantages are that they conduct the current better, are cleaner and more convenient. The cover contains a definite amount of water, hence its resistance does not vary as in the case of a sponge. Pressure may be made with the carbon electrode without drenching the patient with an overflow of water, and without the risk of touching the skin with the edge of the metallic cup which is very painful. A clean cover may be slipped over the electrode for every fresh patient: no small recommendation in the eyes of many.*

Metallic disks are sometimes used; but besides being heavier than carbon, they have the disadvantage of oxidizing rapidly unless they are plated. The most generally useful sizes for the disks are $2\frac{1}{2}$-3 and 1-$1\frac{1}{4}$ inches. The edge of the disk answers very well the purpose of a fine electrode for localising the current. A small olivary or pointed electrode is often useful for diagnosis, and is advantageously made with a curve, as in fig. 79.

I cannot too strongly recommend the use of plates of tin as stable electrodes, both as regards efficiency and convenience. They are pliable and can be made to fit accurately any part of the body; they are readily slipped under the patient's dress, and are there kept in place by the pressure of the clothes, without any effort to hold them.

In many cases, for instance, the positive pole is advantageously placed on the nape of the neck: A plate is then simply slipped under the patient's collar and there remains firmly applied, leaving both the operator's hands free.

As regards the size and shape of these plates, an oval, 3 inches by 2, will be found generally convenient. Like the disks they are placed in flannel or wash-leather covers,† and moistened with water. In order to avoid wetting the patients clothes, one side of the cover is to be covered with oil-silk or india-rubber tissue. The plate is either permanently connected with the rheophore by means of soldering, or provided with an appropriate binding screw.

An electrode which is occasionally resorted to, is the operator's hand or finger; the *modus operandi* will be found described under Faradisation.

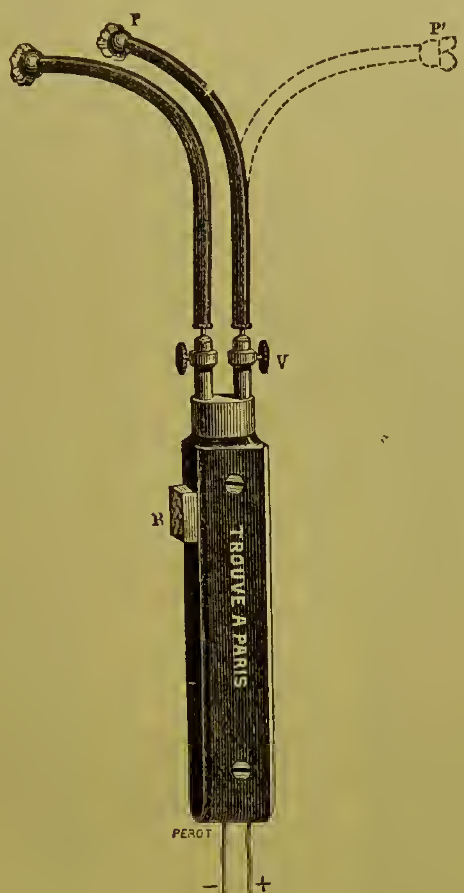
* Not long ago the child of a physician in Florence, was electrised at the hospital for some paralytical disorder. A few weeks after a distinctly syphilitic rash made its appearance. It was found, on inquiry, that the sponges used had been employed in the case of a patient infected with syphilis.

† Special care must be paid to these covers, which must be substantial, as otherwise unpleasant eschars will be produced.

Many forms of special electrodes have been devised for the bladder, the rectum, the uterus, the throat, ear, eye, etc., and are occasionally required, but need no description here.

The bipolar electrode consists of a single handle carrying two

FIG. 77.

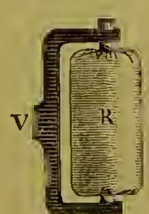


Trouvé's bipolar electrode.

carbon disks, connected with the two poles of the battery.

The roller electrode allows of its being displaced without pro-

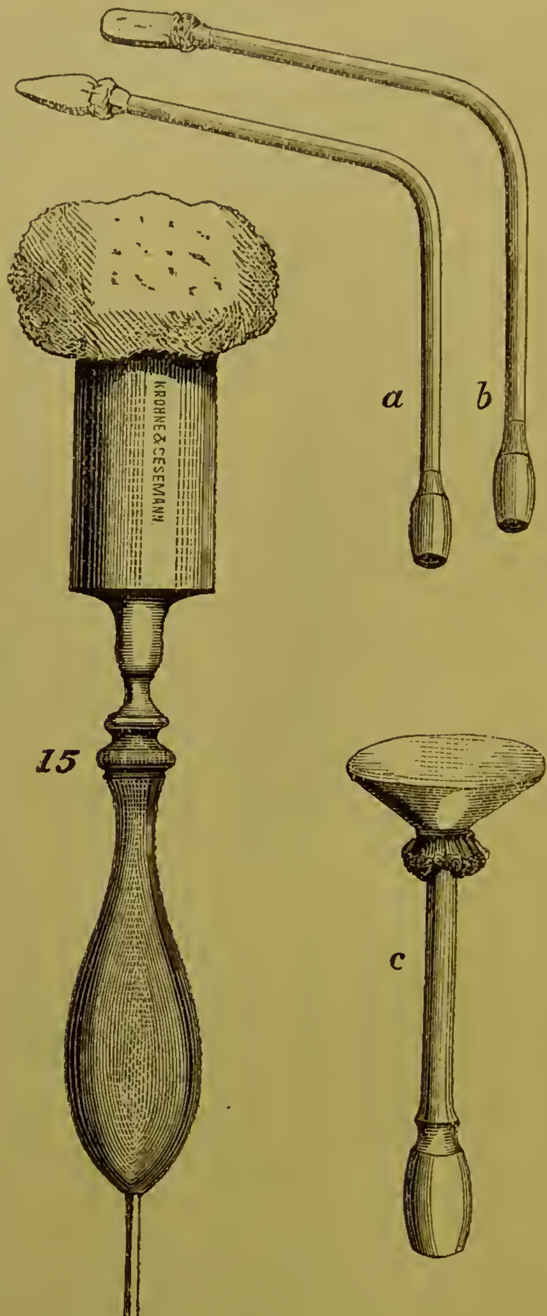
FIG. 78.



Gaiffe's roller; the handle screws in at V.

ducing any variation in the current. Its main employment is in electrolysis where one pole only is connected with the needles.

FIG. 79.



Electrodes.—Sponge holder, carbon disk, and olivary carbons for testing single muscles.

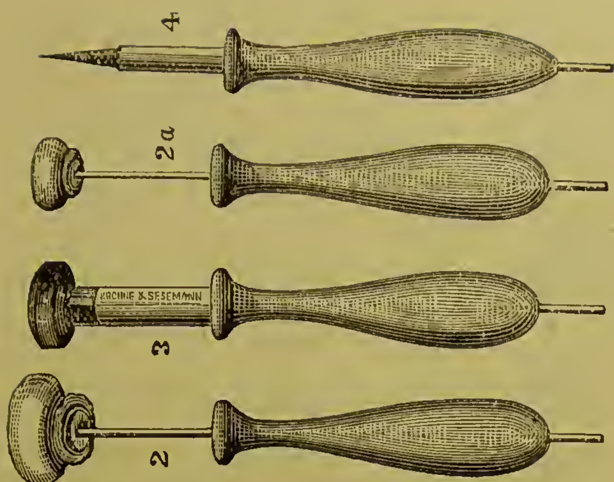


FIG. 80. Other shapes of carbon electrodes; and pointed electrode for localising the current.

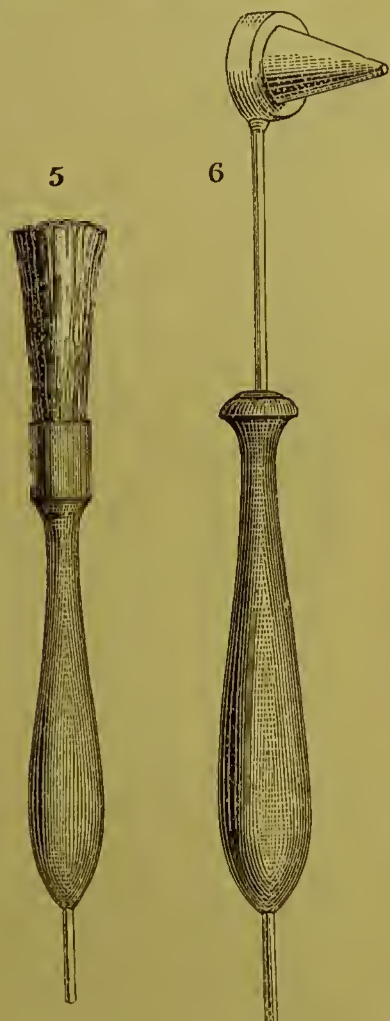
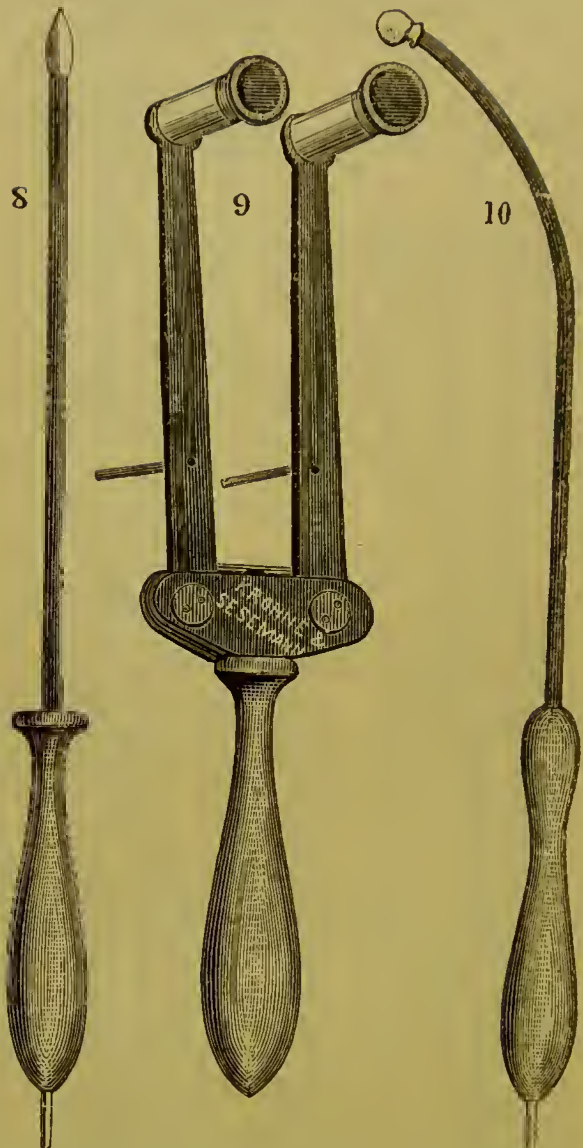


FIG. 81. Wire brush; ear electrode; interrupting handle.

Fig. 82.



Bifurcated electrode and long electrodes for throat, uterus, urethra, etc.

A few words may be added here, touching the moistening of the electrodes. When the battery is weak, and especially when sponges are used, warm salt water is requisite. Otherwise pure water, cold or tepid, according to the season or sensitiveness of the patient is enough. The addition of a few drops of aromatic vinegar makes it pleasant, and enhances its conductivity. The prolonged and repeated application of salt to the skin irritates and roughens it, an objectionable result in the eyes of some patients. The addition of either salt or vinegar hastens the corrosion of copper, which,

as it cannot be entirely banished from the construction of rheophores, must always be strongly plated. Nickel or silver plating ought, in fact, to be applied to all the accessories of a battery, dials, commutators, binding screws, etc.

Dry electrodes are used solely for the purpose of cutaneous faradization, and consist usually of a metallic brush or cylinder, without any covering. The brush is best made of nickelised copper wire, and has usually the shape of an ordinary painter's brush, as in fig. 81. For applications to large surfaces, it may conveniently be made in the shape of a clothes brush, with bipolar arrangement. The metallic cylinder needs no special description. A metal or carbon disk, stripped of its cover, answers very well the purpose of a dry electrode.

Electrodes may be attached to either end of the handle, as shown in fig. 85, M and M'. For ordinary purposes it is best to have the connection, as at M, that is at the junction of the handle with the carbon disk.

FIG. 83.

Trouvé's roller electrode.

INTERRUPTORS.

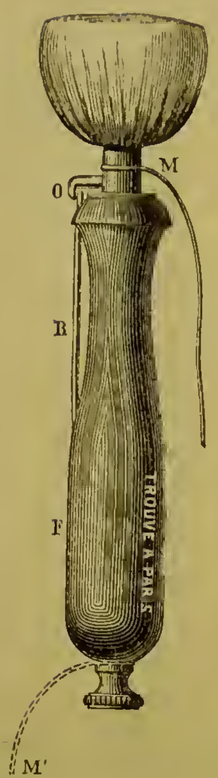
THERE are two modes of interrupting the current during an application. First, by leaving one of the electrodes in contact with the skin, whilst the other is successively applied and removed. Second, by leaving both *in situ*, and making and breaking the current in the metallic portion of the circuit. The former is sufficient for rough diagnosis and treatment; but for accurate work a contrivance for effecting the latter is necessary.

In some batteries a special interruptor is provided, or the commutator is used for the purpose. But this arrangement is far less convenient than the interrupting handle, which I consider an almost indis-

FIG. 84.

Gaiffe's interrupting handle.

Fig. 85.



Trouvé's interrupting handle.

pensable instrument for electro-diagnosis. It consists of an ordinary electrode handle, inside of which a spring is concealed. Pressure being made with the finger upon an ivory button protruding externally, the spring is depressed and contact broken. The contact surfaces are to be, of course, kept clean, and are best made of platinum. Other shapes of interrupting handles have been devised, which need not be described here. A rough interruptor may be improvised by connecting the end of the rheophore with an ordinary sewing thimble capping the index finger. By then touching with the latter any metallic part of the electrode held in the hand, the circuit is closed and the current flows. Fig. 54.

Pedal interruptors have also been devised, and are mainly used for producing slowly interrupted faradic currents.

Toothed wheels for obtaining rapid interruptions are provided in some batteries. The objection to them is, that they often give double shocks, and are very liable to get out of order.

Automatic interruptors, as the toothed wheel moved by clock work, the metronome and mercury cups, etc. have hitherto been rarely used for medical purposes. Brenner's interruptor is an ingenious application of an electrical contrivance adopted in some telegraphs. Dr. Onimus' interrupting apparatus will be found described along with the induction batteries.

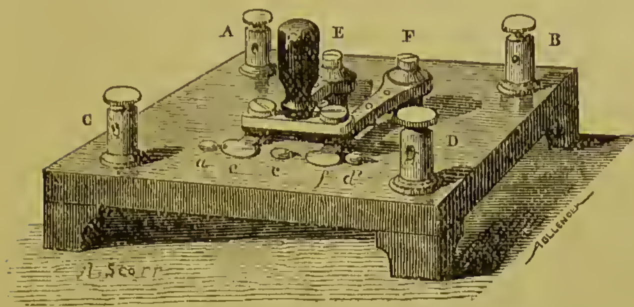
Current Reverser or Commutator.

It is often necessary for purposes of diagnosis or treatment to be able to reverse the current through the electrodes whilst *in situ*.

For this purpose several contrivances have been devised. The most familiar is the barrel commutator and its modifications, depicted in the illustrations of some of the batteries figured in this book. The only observations to be made here are, that the handle of the commutator should be large enough to allow of its being worked comfortably; and that when the full effects due to "voltaic alternatives" are desired, the commutation should be immediate, *i.e.*, that there should not be an interval during which the current is opened in the act of commutation.

Another convenient commutator is made in the shape of two springs playing upon three studs, similar to those used for the dial collector.

FIG. 86.



Gaiffe's current reverser, or commutator. A B, binding screws receiving the heophores from the battery, and connected with E F respectively, which are the pivots upon which the two handles E e, F f, revolve. The hands consist of a spring, e f, fixed to the inferior surface of a rigid piece of brass; a transverse piece of ivory, surmounted by a handle connects the two brass rods, and serves to move them laterally.

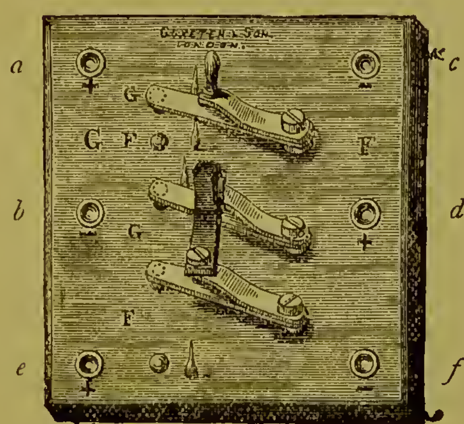
C D, are the binding screws for attaching the external rheophores, C being connected with c, D with d′. The latter are metallic heads upon which e and f are made alternately to rest. A glance at the picture will show that the direction of the current is changed in C D, according as to the position of e f, on d c, or c d′ respectively.

The see-saw mercury commutator may be used for stable batteries; but has hitherto been mainly confined to the physiological laboratory.

CURRENT ALTERNATOR AND COMMUTATOR.

AN instrument for passing the galvanic and faradic currents alternately through the same rheophores is described by Benedict in his

FIG. 87.



The wires from the galvanic battery are attached to *a*, *b*; those from the faradic to *c*, *d*; the rheophores to *e*, *f*. When the index rests on G as in the figure, the instrument acts as a commutator, the current being direct, (*i.e.*, according to the signs + and —) through the rheophores when the double handle encloses G as represented, indirect when it encloses F. When the index is on F, the corresponding positions of the handle allow the galvanic and faradic current to pass respectively, both being direct.

Electro-therapie. But it does not seem to have been satisfactory, and he has abandoned its use.

It is, however, frequently convenient to be able rapidly to pass from one current to the other; and I have accordingly devised a little instrument that supplies this want, and at the same time acts as current reverser and interruptor, so as to avoid the undue multiplication of accessories to the battery.

The instrument is adapted either for stable batteries, and is then best made of full size; or for portable apparatus, to the element board of which it may be fitted. A "separable-combined" battery may thus be obtained, which possesses the advantages of the usual form of combined instruments, without their inevitable drawbacks, such as of both the component parts being thrown out of use when one requires repairs. A separable-combined battery may be readily made out of any galvanic battery by simply supplying it with the alternator, and a compartment into which a faradic instrument of appropriate size can be lodged.

CHAPTER III.

ELECTRO-DIAGNOSIS.

THE NORMAL POLAR REACTIONS.

Contractions occur only when the current is made or broken. Hence it is evident that we can distinguish 4 kinds of such contractions according as to which pole is on the muscle, and which change occurs in the current:—

1. The cathodal closure contraction (C. C. C.) occurs when the negative pole (cathode) is on the muscle, and the current is made (circuit closed).

2. The anodal closure contraction (A. C. C.) occurs under the same circumstances, when it is the positive pole (anode) instead of the negative.

3. The cathodal opening contraction (C. O. C.) occurs when the negative, and the (4) anodal opening contraction (A. O. C.) when the positive pole being on the muscle, the current is broken (circuit opened).

Now these several contractions do not occur all at once, that is, with the same strength of current. Fix one of the electrodes on a neutral point of the body, the sternum or sacrum, and hold the other upon some muscle of easy observation, such as the abductor of the index. Now try gradually increasing the current, and making the poles alternately positive and negative, which of these contractions manifests itself the first. You will find that the C. C. C. is the first to appear. Increase the current still further, and soon

the A. O. C. appears, followed closely by the A. C. C. Last of all, and only with a current so strong as to be unbearable, unless unpolarisable electrodes be used, the C. O. C. manifests itself. It is also observed that the previous contractions tend, as the current-strength is increased, instead of being transient, to become prolonged, tetanic.

By "the normal formula" of muscular contraction, we then understand that contraction in healthy muscle occurs in the order just stated, viz.:—

1. C. C. C.
2. A. O. C.
3. A. C. C.
4. C. O. C.

REACTIONS IN DISEASE: REACTION OF DEGENERATION.

In many cases of disease, the reactions of nerves and muscles to electrical currents are found to differ from those observed in health. Such variations may be, 1, *quantitative*, that is to say, consist in an increase or a diminution in the response to a given current-strength, faradic or galvanic; 2, *qualitative*, that is, display an alteration in the order of occurrence of the contractions, as given in the normal formula.

Quantitative variations are often observed by themselves; but qualitative never occur without coincident quantitative modifications.

I. We must first mention the cases of motor disturbance where electro-muscular and nervous investigation does not give any positive results.* Such are paralyses from cerebral hæmorrhage and tumours; paralyses from chronic myelitis; a few peripheral paralyses, such as light cases of traumatic and "rheumatic" origin (compression of musculo-spinal, slight facial palsy; and some other more severe "rheumatic" paralyses.

In such cases then the reactions of the diseased organs do not differ from those given by the sound ones, and allowing us to draw only a negative inference, and to exclude in doubtful cases a number of possible causes.

This is to be borne in mind when *shamming* is suspected. The absense of electrical-diagnostic symptoms is no proof in itself of the unreality of the disease. The converse of this proposition, however, is true, and we are enabled from the presence of alterations in the electrical reactions of nerves and muscles, to conclude to the reality of the alleged lesion.

II. Mere *quantitative* variations, though sufficient to prove that there must be some change in the nervous or muscular tissue are not of great diagnostic importance.

* The term *electro*-irritability, should be carefully restricted to its generic sense, including within it both galvano and farado-irritability.

A. *Simple increase* of response to the electrical currents is rarely met with. It has been observed in some cases of hemiplegia; of spinal diseases, such as locomotor ataxy; and transiently in some peripheral paralyses, such as the very early stage of facial paralysis. It is also observed in some cases of chorea.

B. *Simple diminution* may culminate in total abolition. It is observed in the later stages of bulbar paralyses; more frequently in spinal paralyses from myelitis, when it is accompanied with atrophy of the muscles; and in certain paralyses appearing as sequelæ of acute diseases. It also accompanies progressive muscular atrophy, where it is proportional to the amount of local wasting.

III We now pass to the group of diseases which are characterised by both *qualitative and quantitative* changes, or as it is called, by the "Reaction of Degeneration." The phenomena exhibited by nerves and muscles must be considered separately.

1. In a typical case, where the invasion of the disease is sudden (such as traumatic lesions), two or three days after the paralysis has declared itself the reaction of the nerve to both currents begins to diminish rapidly, and becomes extinct by the tenth to twelfth day.* In incurable cases it never re-appears. In the others it re-appears, remarkably enough, only after the return of volitional impulse has manifested itself in the nerve. It then slowly increases, and likewise reaches its normal point after the full power of the will over the paralysed parts has been re-established.

2. The muscles behave absolutely like the nerves with regard to their farado-contractility;† by the end of the second week it is lost. The galvano-muscular contractility is at first somewhat lowered, but soon ascends again to its normal level, and beyond it, so that a much weaker current is sufficient to stimulate the diseased muscles than the corresponding sound one. At the same time *qualitative* changes manifest themselves. The order of the normal formula is disturbed and the positive pole becomes as powerful as, or surpasses, the negative at the closure, whilst the opposite obtains at the opening of the current. The ACC occurs as soon as, or before the CCC, and the COC as soon as, or before the AOC.

The muscles do not contract as forcibly and rapidly as in health, but more slowly; the closure contractions become tetanic; and rapid interruptions of the galvanic current do not elicit any contraction at all. The evolution of the different stages in the reactions correspond to definite histological changes at the seat of the disease. The appended diagrams will help to make this more evident. The disappearance of farado-contractility is due to the degeneration of the nerve-endings in the muscles.

The reaction of degeneration accompanying the following peripheral paralyses. Traumatic (from pressure or wound) where there is complete interruption in the continuity of the nerve. "Rheu-

* When the invasion is slow, this period naturally extends over longer intervals.

† There is absolutely speaking no such thing as farado-muscular contractility. The term is a convenient one, however, and must be taken in the sense of reaction to faradisation of the muscle itself, that is of the intra-muscular nervous fibres and endings.

matic" (especially facial) when there is compression at some point of the nerve. It is found also in some cases of neuritis, and wherever the nerve is seriously interfered with by pressure, as from tumours, cicatrices, etc.

It also characterises lead palsy, infantile paralysis, and all spinal diseases where any part of the grey matter is gravely affected, such as spinal apoplexies. It appears in progressive muscular atrophy, bulbar paralysis, and some paralyses following acute diseases.

The diagrams here appended are designed to show by means of curves, the course of the phenomena presented by the reaction of nerve and muscle to electrical stimulus in the cases above mentioned, and their correlation with the accompanying histological changes. Three categories of cases are depicted; one of rapid recovery, one of slow recovery, one of no recovery. The curves, of course, do not pretend to convey any idea of definite proportion of the amplitude of the changes—but simply of their mutual chronology and general rate of progress.

The first ordinate, marked O, indicates the first manifestation of the paralysis, the sudden loss of voluntary motion. Motility is indicated by the dotted line; and the star points to the time of its reappearance.

The following numbered ordinates indicate the time over which the phenomena extend in weeks. The galvano-contractility of muscle is represented by a continuous line, wavy to indicate the period of qualitative alterations; the curves, of course, denoting the quantitative changes, as in the other lines, which need no further explanation to be understood.

In the diagram A the following facts are illustrated: during the first week the reaction of both nerve and muscle falls to all currents. In the course of the second week the galvano-muscular reactions begin to rise and show signs of qualitative alteration. The farado-muscular and electro nervous irritability continue to sink till they vanish altogether. The course of the quantitative and qualitative phenomena of galvano-muscular reaction is easily followed, and their dependency upon changes in the muscular and nervous tissues appreciated by a glance at the curves. It will be observed that motility, the loss of which is synchronous with the invasion of the disease, reappears before either farado-muscular or electro-nervous irritability, and heralds corresponding regenerative changes in the nervous tissue.

From the explanations given for diagram A the meaning of B and C will be easily made out.

It must be remembered that these diagrams are not meant to illustrate any particular cases, but the 3 types of cases, these types being the fruit of generalisations from a large number of observations. Further there occur departures from the typical course of phenomena presented by the reaction of degeneration, of these anomalous cases no explanation can yet be given, though they may in time throw some light upon the problem of trophic influences. For instance, cases are met with where the quantitative

Fig. 88.

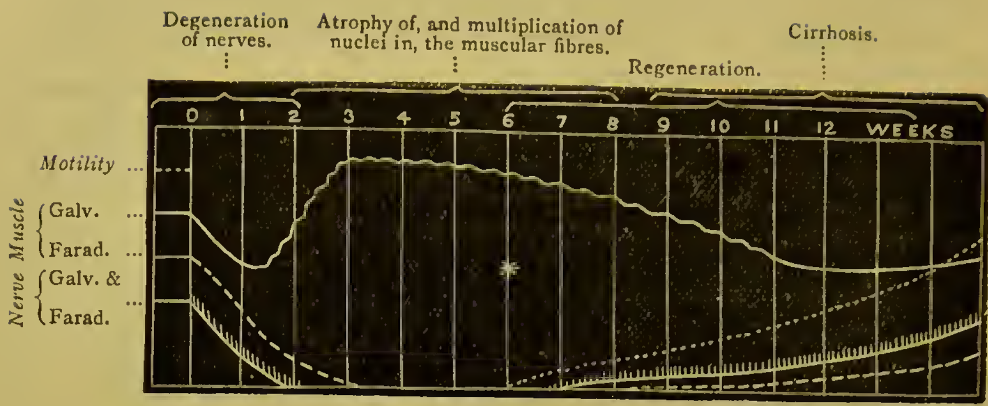


Diagram A. Recovery rapid.

[N.B. The slope of the line indicating the fall of farado-muscular contractility should have been made more abrupt so as to end near the bottom of line 2].

Fig. 89.

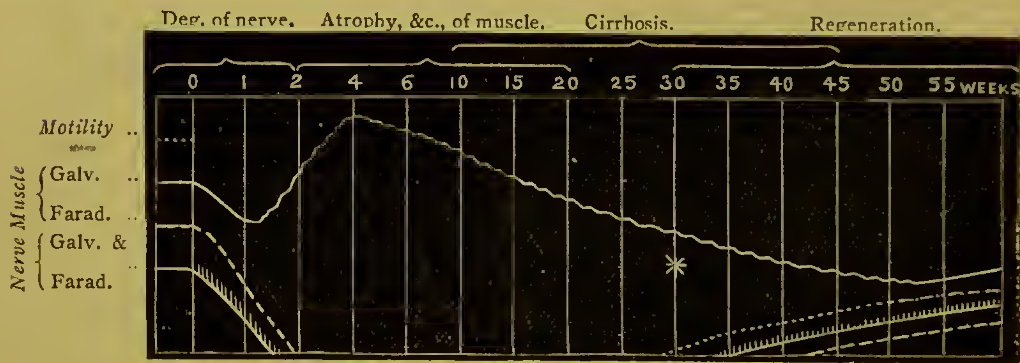


Diagram B. Recovery slow.

Fig. 90.

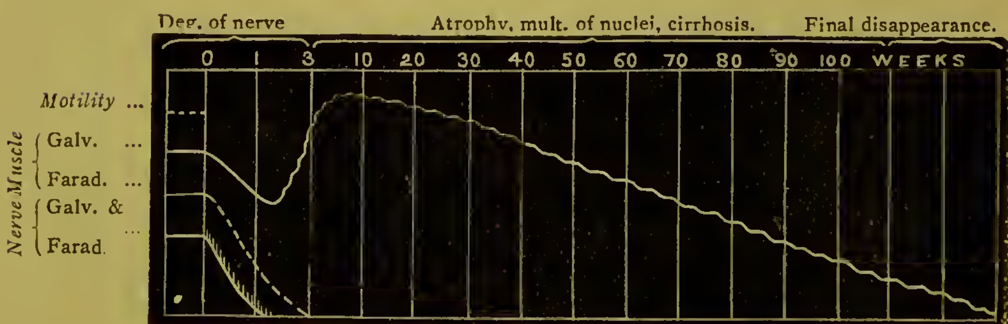


Diagram C. No recovery.

galvano-muscular changes are not observed, the qualitative being present along with nervous unirritability. Again the electro-nervous irritability may be only slightly diminished, whilst the muscles conspicuously display the usual phenomena of qualitative and quantitative alteration. This anomaly may persist for a time after recovery, and points to muscular disturbance without corresponding nervous changes. This incomplete form of the reaction of degeneration, is observed in amyotrophic lateral sclerosis, the "middle form" of facial paralysis, the earlier stages of bulbar paralysis and of progressive muscular atrophy. In the last two it must be noted, however, that the quantitative deviation takes the form of a diminished irritability to the galvanic current, and that the utmost care is required to recognise the abnormal reaction of the diseased fasciculi, surrounded as they are with still healthy tissue. Prof. Erb has lately carefully examined a case of lead poisoning, where some muscles presented similar phenomena: there was no paralysis; the galvano and farado-nervous irritability was fully preserved; yet the reaction of the muscles offered the characteristic quantitative as well as qualitative alterations.

The following diagram is intended to assist the reader in realizing the interdependence of certain pathological changes with the phenomena degenerative reactions. It is, of course, purely imaginary. Not only the locality of the trophic centres has never been demonstrated, but their very existence is disputed by some. Still as a provisional hypothesis, assisting to group together new facts as they are discovered, it may be found useful to assume not only the mutual independence of the motor and trophic centres, but of the trophic centres presiding over the nutrition of muscles and nerves respectively. We start from the well established facts, 1. that trophical changes occur in nerve and muscle independently of paralytical phenomena, and *vice versa*; 2. that such trophic changes occur in both muscle and nerve, or in muscle only.

The point of convergence of the trophic, as well as of the voluntary and reflex influences, is supposed to be in the multipolar ganglion-cells.

The interpretation of various morbid states by means of this diagram may be found interesting.

Thus if the lesion be at c, or what comes to the same thing in the cerebral centres above, we have as characteristic symptoms, paralysis (loss of motility), but no atrophy, and no loss of electro-irritability of either nerve or muscle. The disease is cerebral hemiplegia, or lateral sclerosis.

If the lesion involves both c and m we have paralysis with atrophy of muscle, but not of nerve. Electrical reactions: qualitative and quantitative changes in galvano-muscular irritability; no change in nerve, which responds to both galvanism and faradism. The disease is amyotrophic lateral sclerosis.

The lesion is confined to the trophic centre (m) of the muscle: it atrophies, but is not paralysed. It presents the qualitative alterations of reaction of degeneration; the quantitative changes are in the direction of a diminution of galvano-contractility. These

phenomena occur in progressive muscular atrophy and bulbar paralysis.

When G is destroyed there is loss of motility, loss of reflex action, atrophy both of nerve and muscle. The electrical phenomena are those of the reaction of degeneration fully developed. The same obviously obtains when N is completely (*i.e.*, including m′ and n′) destroyed at one point. G is destroyed in anterior poliomyelitis (infantile paralysis); N in severe peripheral paralyses, whether from traumatic, rheumatic, or any other cause.

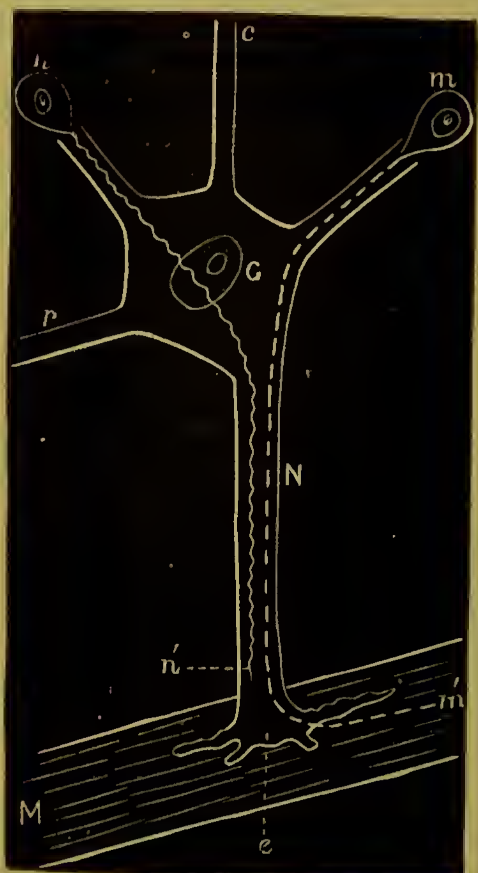
There are, however, many instances of peripheral paralysis, where the loss of voluntary motion exists, and yet the other symptoms are not those of the "severe" forms just mentioned; they may be conveniently classed under the heads, as the "light" and the "middle" form.

In the light form paralysis is the *only* symptom. All the reactions, are perfectly normal, we must then assume that N is interfered with only in its conductivity for motor impulse.

In the middle form there is atrophy of muscle and qualitative changes of galvano-contractility. Electro-nervous irritability is perfect. Here there is in addition a lesion of the path m-m′.

In lead palsy, which is characterised by atrophic changes in nerve and muscle, the reaction of degeneration is most fully developed.

FIG. 91.



Explanation of Diagram.

M. Muscular fibre.

N. Nerve fibre. with its ending, e.

G. Multipolar spinal ganglion-cell, from the anterior horn of grey matter.

c. Path of impulse from the brain (lateral fasciculi).

r. Path of reflex stimulation from the sensory sphere.

m. Trophic centre for the muscle.

n. Trophic centre for the nerve.

m-m′. Path of trophic influence to the muscle.

n-n′. Path of trophic influence to the nerve.

SYNOPTICAL TABLE, SHOWING THE CONNECTION BETWEEN CERTAIN PATHOLOGICAL STATES AND THE ELECTRO-DIAGNOSTIC PHENOMENA ACCOMPANYING THEM.

SEAT OF LESION.	PROMINENT SYMPTOMS.	ELECTRICAL REACTIONS.	NAME OF DISEASE.
c	Paralysis No atrophy.	All normal	Lateral sclerosis (and cerebral disease).
c & m	Paralysis Muscular atrophy.	*Nerve:* Normal. *Muscle:* Reaction deg.	Amyotrophic lateral sclerosis.
m	At first no paralysis; muscular (later nervous) atrophy.	*Nerve:* Normal, later diminished. *Muscle:* Qualitative alteration. Quantitatively diminished.	Progressive muscular atrophy. Bulbar paralysis.
G	Paralysis Atrophy of muscles and nerves. Abolition of reflex actions.	*Nerve:* } *Muscle:* } Reaction deg.	Poliomyelitis anterior. (Infantile paralysis).
N	Paralysis No atrophy.	All normal.	Light form of Peripheral.
N & m	Paralysis Muscular atrophy.	*Nerve:* Normal. *Muscle:* Qualitative and quantit. alter.	Middle form.
N m′ & n′	Paralysis Musc. and nerv. atroph.	*Nerve:* } *Muscle:* } Reaction deg.	Severe form.

ON THE PRACTICE OF ELECTRO-DIAGNOSIS.

Method.—Owing to the labours of many distinguished observers, the art of electro-diagnosis has begun to assume an important position in medical practice. Pathologically it offers many points of interest, and will amply repay the trouble of mastering the details necessary for its successful application.

In studying the reactions of muscles and nerve to electricity, the following points are to be noted. The disease is either unilateral or bilateral.

A. If unilateral the state of the muscles and nerves on the paralysed side are to be carefully compared with that of those on the sound side. For this purpose it is absolutely necessary that the conditions be exactly the same on both sides.

First: The muscles must be in a state of absolute rest, and equally relaxed on both sides.

Second: The points to which the electrodes are applied must exactly correspond on either side.

Third: Absolutely the same strength of current must be used in comparing the muscles on either side.

In order to fulfil these conditions, we must first take care that the patient be comfortably sitting or lying, and instruct him to avoid any voluntary movement. Care must be taken that the light be good, and fall so that the shadows do not interfere with the observations. When the arms are tested it is convenient to let them rest across the back of a chair on which the operator sits astride.

2nd. Use a bifurcated rheophore and two interrupting handles with small carbons. The latter are to be placed carefully on the corresponding points, and held firmly in situ, the current being alternately made and broken on either side. Slight differences are thus much more quickly and accurately observed, than when the same electrode is dabbed now on one muscle, then on the other. When strong currents must be used, as is frequently the case, dabbing is a very painful process. In any case sponges are utterly to be rejected for accurate diagnosis.

3rd. Use for the other pole, a metal plate which is firmly fixed to a point in the middle line of the body; the nape of the neck and the lumbar region do very well when the upper or lower part of the body is affected. Care must be taken that no displacement of the plate occur during the operation. A turn of bandage must be resorted to, when the pressure of the patient's clothes is not sufficient. The skin on the two sides must be thoroughly moistened; and care taken that the metallic contacts of the interrupting handles be not oxidised.

For the reasons stated above, whenever practicable, a high tension current is to be preferred for diagnosis, and the galvanometric readings recorded, so as to be able to compare accurately the results obtained by future examinations.

B. The paralysis is bilateral. It is very difficult in cases of paraplegia, for instance, to discover a slight quantitative alteration of electro-contractility on account of the want of a point of exact comparison. The operator must then appeal to his experience of what average current-strength is required to excite contractions in the given muscles. The two sides are at all events to be compared, as frequently they differ in the amount of disease present, the same rules being followed as before. Qualitative alterations, on the other hand, must obviously be as easy to discover in bilateral as in unilateral paralysis.

General directions.—Proceed carefully and deliberately. Though in the majority of cases a mere superficial examination may be sufficient to demonstrate the nature of the disease, still the habit of performing electro-diagnosis in a slovenly manner is to be deprecated. The finer gradations present in all cases escape notice, and great difficulty is experienced afterwards, when a more obscure case happens to turn up, in obtaining satisfactory results. It is owing to

faulty methods as much as to defective apparatus, that many phenomena of the reaction of degeneration has so long escaped the notice of observers. And it must not be thought an easy matter to obtain evidence of it wherever it exists. Accuracy of manipulation and of observation are indispensable.

First find out the minimum current-strength which is capable of producing contraction in the healthy muscle, and compare it with that necessary to stimulate the diseased one. The effect of both currents and of both poles in the case of the galvanic is to be tried; for this purpose the current-alternator and commutator will be found convenient in the absence of a combined battery.

Begin with faradism. If a powerful current is required to excite contraction, rapid interruptions must be avoided, and not more than ten or twenty in the minute made. In the absence of the pedal rheotome this may be done by working the hammer with the finger. It must be remembered that the so-called negative pole of the faradic current has a more powerful effect than the positive, and that they cannot, therefore, be indiscriminately used for purposes of exact diagnosis.

Several examinations are often necessary in order to attain certainty and completeness. It is also useful to repeat them at intervals so as to watch the progress of the case, and note the evolution of the degenerative reactions if they manifest themselves.

When the effect of faradism has been observed the same process is repeated, first with the negative, next with the positive pole of the galvanic current. If the mere interruption of the current does not produce contractions, the effect of voltaic alternatives must be tried. Note also whether rapid interruptions fail to produce contractions.

When strong currents are used, great care must be taken to discriminate the effects due to stimulation of neighbouring muscles masking or counteracting any contraction of the muscle observed.

Precautions must be taken not to mistake effects due to the diffusion of the current in testing the electro-nervous irritability. Numerous observations are on record, the results of which are entirely fallacious from want of attention to the physical conditions of electro-diagnosis.

CHAPTER IV.

ELECTRISATION.

It is to be feared that, for many people still, the idea conveyed by the term "electrisation" is that of holding a copper cylinder in either hand and receiving tremendous shocks through both arms. Nay, it is but too probable that this mode of torture is still occasionally inflicted upon patients. It is not, therefore, wholly unneces-

sary for us here to protest against this relic of barbarism, and inform those who might be tempted to put it into practice, that it is as useless as it is irrational. It should not be forgotten that it is not so much "electricity" that cures as "electrisation," that is, the rational application of electricity. The choice of the current to be used, its dosage, and the general methods to be followed in different cases are of primary importance. The often-used expression "trying electricity" conveys about as much meaning as to speak of "trying water" without specifying whether the water is to be hot or cold, in the shape of ice or steam, applied externally or internally, and so forth. Exactly as the soothing influence of a hot bath, for instance, differs from the exciting action of a cold douche, so does the sedative influence of a mild, continuous galvanic current differ from the stimulating effect of an interrupted faradic current. Where the one is beneficial, the other is useless or hurtful.

It is certain that in many cases where, injudiciously treated, the patient has, besides suffering much unnecessary pain, found his symptoms aggravated; the fault then lay not so much with electricity, as with the electriser. Every one who prescribes or applies electricity must pay the same attention to the administration of this powerful agent, both as to quantity and mode of application, as he would to that of any other therapeutical means.

It may be put down as a general rule that whoever will apply electricity rightly to others, should have first tried it upon himself. This practice is doubly useful. It teaches far more quickly and surely than anything else, both what to avoid, and what to do in order to be a successful operator. It is indeed difficult to understand how galvanism and faradism can be intelligently, painlessly, and even sometimes safely, applied by one who has no personal experience of the sensations produced by the currents. A general idea of the art of electrisation is very speedily obtained by a few trials upon oneself. The different sensibilities of different parts of the body, the motor points of muscles, the mode of applying the rheophores to the skin, of graduating the current, etc., will be vividly realised and readily mastered. The numerous details in the application of electricity conducive to the comfort of the patient and efficiency of the treatment, can be learnt by experience only, and above all by personal experience.

Avoid all unnecessary pain. The seat of pain is chiefly in the cutaneous nerves, and it will be found that where a strong current must be used, the application will be much less painful if the electrodes are held firmly pressed upon the skin; the more lightly they touch the surface, the more intolerable the sensation produced. In nervous or thin skinned patients, in children, and whenever the head and neck are to be electrised, it will be found advisable to place the rheophores *in situ* before the current is turned on; and then to bring it very gradually up to the desired strength. Likewise at the end of the sitting it is best not to remove the electrodes suddenly, but gradually to diminish the current so as to avoid an unpleasant shock. It is a good policy with children, and nervous

people who, at first especially, the very contact of the electrodes agitates, to wait a short time before turning on any current at all.

Habit not only makes patients more confident, but enables them to bear stronger currents comfortably. Electricity in this respect is like many other therapeutical agents. In fact it is often necessary to increase the doses as tolerance becomes established. One thing, however, must be borne in mind, that the skin never gets accustomed to the chemical action of the current; and though the patient may not complain, unpleasant eschars are sure to follow too strong or too prolonged applications.

Whenever the electrodes are to be applied with the current already turned on, it should be made an invariable rule for the operator to try it on his own hand, or face, as the case may be, before touching the patient.

GALVANISATION.

Galvanisation is either continuous or discontinuous.

A. *Continuous.*—This has been called the *stabile* method. During the whole appplication the rheophores are immovably held upon two points of the body, so as to include between them the organs to be acted upon by the current. The main point to be kept in view, is the perfect steadiness or constancy of the current. To secure this the following rules must be observed:—

The rheophores must be firmly applied to the skin before the current is made. The current is to be gradually increased up to the desired strength, and at the end of the sitting gradually diminished before the rheophores are removed. (This implies the existance in the battery of a rheostat, or of a collector enabling to increase without jerks the current by two cells *at most*). During the whole application, care must be taken that the rheophores be kept in place, and that no interruption occur.

This especially applies to applications about the head and neck, and whenever the patient is at all nervous. If not actually dangerous, sudden variations in the strength of the current flowing through the body are exceedingly unpleasant; and for many reasons the patients' comfort has to be studied by the medical electrician.

A more important reason for paying attention to this particular is the fact that any shock interferes with the purely sedative effect generally sought when the stabile method is used.

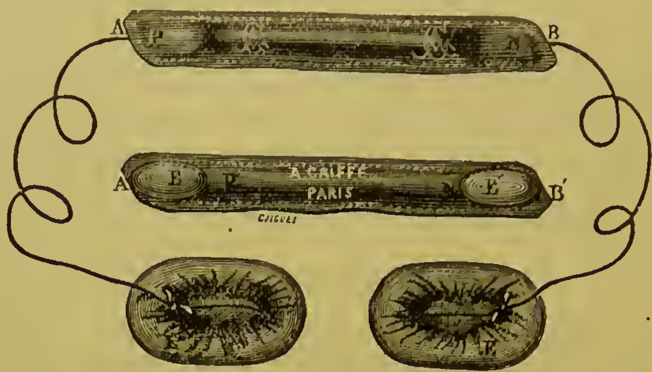
As to the *duration* of stabile applications we may distinguish, 1st, *temporary* galvanisation which is the method now universally adopted. The time taken by an electrical sitting varies from 2 or 3 to 10-20 minutes, usually repeated daily or every other day.

2nd. *Permanent* galvanisation consists in using a weak current for many hours at a time. Experience has shown that it has no advantage over temporary applications, whilst its drawbacks are many, such as the production of very troublesome eschars on the skin. The only survival now extant of this practice is the use of galvanic chains and other such paltry inventions. After enjoying an ephemeral success, these wares have sunk into the domain of "patent medicines," where we are glad to leave them. Those

anxious to learn their virtues will find them fully described in the advertisement sheet of most daily papers.

If, however, permanent electrisation should appear advisable in any special case, recourse may be had to Gaiffe's small chloride of silver elements, arranged as in the figure. Two to eight such

FIG. 92.



Small batteries for permanent applications. A, B, bag containing the cells. E, E, electrodes; N, P, indicate the positive and negative poles.

cells are disposed in a leather bag which is carried next to the skin with the electrodes properly disposed. The current is very constant, and flows continuously from 100 to 150 hours.

B. Discontinuous.—The *labile* method forms a transition between the stabile just described, and the interrupted. It consists in keeping the positive pole applied to one point, whilst the negative is used for "sponging" the diseased limb, or portion of the body. This is effected by passing the electrode all over the surface to be acted on, with a moderate amount of pressure. Without necessarily producing any marked muscular contractions, labile applications are much more stimulating than the stabile. The current is not actually broken at any moment, but is subjected to numerous small variations of strength, owing to the unevenness of the skin, etc, and acts with an always changing density upon the underlying muscles, the current being densest in the part immediately beneath the electrode. The amount of muscular contraction produced by labile applications is then dependent as much upon the rapidity of the motion, as upon the strength of the current used. Labile currents are indicated where, in addition to the chemical action of the stabile current upon the deeper structures, we wish to call forth moderate contractions of all the muscles, and increase the cutaneous circulation over a wide area, and thereby stimulate the nutrition of a limb.

There are two ways of using the *interrupted* galvanic current.

One of the poles may be held immovable on some points of the body, while the other is dabbed over, or made to touch lightly, the skin at the part to be stimulated.

Or the two poles may both be kept in contact with the skin, whilst the interruptions are made in the metallic part of the circuit by means of one of the contrivances we have described. When strong currents are to be used, the latter method must be preferred,

being much less painful. It is the only reliable one for obtaining accurate results in electro-diagnosis. The interrupted current is stimulating, and is chiefly used for causing contractions of the muscles. When the makes and breaks succeed rapidly to one another, 800-1000 a minute, the muscle is thrown into a state of permanent or tonic contraction.

The negative pole is to be applied over the muscle to be stimulated, being much more active than the positive, at least whenever the muscular reactions are normal.

Interruptions are never to be used about the head and neck without the utmost caution; giddiness, nausea, flashes of light are produced very easily, to the great discomfort of the patient.

The reversed current.—The two poles being held in contact with the patient's body, the direction of the current is suddenly reversed by means of the commutator. The effects produced are much more powerful than those obtained by mere interruptions of the current. In the latter, the electrical state of the tissues pervaded by the current simply oscillates between 0 and x potential (x being determined by the strength of the current used). When the current is reversed, the change is twice as great, viz., from $-x$ to $+x$. In addition to this, two considerations must be kept in mind:—First, that after a current has flowed for a short time through the tissues, a current of polarisation is set up in the opposite direction, which strengthens the reverse current; second, that under the same circumstances, the nerves react more forcibly to a current in an opposite direction owing to increased irritability.

Voltaic alternatives, as such current reversals are called, are indicated, when a still more stimulating application than interruptions is required, and a corresponding degree of caution must be exercised in their use.

Galvanisation of the Sympathetic.

A good deal of discussion has been spent over the so-called "galvanisation of the sympathetic," which has found passionate supporters and passionate detractors. According to the former it would seem that miracles could be wrought by the current applied "to the sympathetic;" according to the latter, it would seem that the sympathetic, by some extraordinary property, entirely escapes the action of the current. The method consists usually in placing one pole in the auricular-maxillary fossa, and the other upon the seventh cervical vertebra. It is evident that, owing to the diffusion of the electrical current, we influence by this means many important nerves, the medulla oblongata, the base of the brain, etc. That good results have so been obtained, it is impossible to deny. But it is equally impossible to ascribe all such results to the sympathetic. On the other hand, those who object to the possibility of galvanising the sympathetic because they do not observe marked changes in the circulation of the corresponding part of the head, and in the state of the pupil, might, it seems to me, deny the continuous passage of a galvanic current through any nerve, because it calls forth

neither sensation nor motion. And there is nothing irrational in the supposition that the repeated action of weak currents may, by their chemical and physiological influence, be followed by therapeutical consequences: we need only advert to the value of atropia, strychnia, etc. in medicinal doses. It must be granted, however, that only weak currents can safely be used in this neighbourhood, and that but a fraction of the current passing through the neck touches the sympathetic, surrounded as it is by better conductors of electricity than itself, *i.e.*, blood-vessels and muscles. The question is still an open one as Ziemssen says; and we look forward with interest to the results of the investigations this distinguished observer has been carrying on of late years. In the meanwhile, we retain the expression "galvanisation of the sympathetic" to indicate a mode of application and nothing more.

FARADISATION.

The subject of faradisation falls under two heads, according as to whether it is the skin or the deeper seated tissues that are to be acted upon.

Faradisation of the skin.—When we wish to localise the effect upon the skin, it is necessary first to dry it thoroughly. This is best done by means of some violet or other powder. The electrode used must be metallic, either in form of a solid cylinder, or of a wire-brush. The method is as follows: place the positive pole (an ordinary moist conductor) upon some neutral part of the body, in the hand, for instance, or on the back, or sternum; then lightly pass the metallic electrode over the dried skin, graduating the current so as to produce a lively crepitation, indicating the passage of sparks between the skin and electrode. The current, however, must not be strong enough to produce any contractions of the underlying muscles.

This mode of precedure is necessarily somewhat painful. When sensitive patients, or sensitive parts of the body, such as the face are to be so treated, it is advisable to use the hand instead of a metallic rheophore. The operator then takes the negative pole (moist) in his left hand and with the back of his right hand, dried and powdered, strokes gently the patient's skin. The same crepitation is heard; and if the current is properly graduated, the sensation to both parties is rather pleasant than otherwise.

Faradisation of muscles and nerves.—In the great majority of cases faradism is applied directly to the muscles through the skin, with well moistened rheophores. The easiest way is to hold the two handles in the right hand, the one between thumb and index, the other between middle and ring fingers, the upper ends of the handles resting in the palm. The left hand is then free to graduate the current, a most important point to be attended to, for different muscles require different current-strengths to react fully, and different parts of the body vary greatly in sensitiveness. A current well borne on the back of the forearm, for instance, will cause pain if applied to the front.

The two rheophores are then passed up and down over the whole surface of the muscle, so as to ensure the thorough contraction of all its constituent bundles. On doing this it will be observed that, in the case of many muscles, there is one point where the effect is much more marked, and that when one of the rheophores is upon it, the whole muscle is thrown at once into a powerful contraction. This point is the "motor point" of the muscle, and corresponds to the point of entrance of its nerve. The knowledge of these points, therefore, enables us to obtain the maximum effect with the minimum current strength. This is of some importance as enabling us to obtain the desired results with the smallest amount of pain to the patient. For this purpose it is advisable to place the negative pole upon the motor point, whilst the positive is held over some other part of the muscle, or over some neutral part of the body. Localising the current at the motor points is also important in electro-diagnosis, when the task is to find out exactly the muscles injured, and the relative amount of mischief in each.

Faradisation of the nerves is rarely resorted to, and mainly for inducing contractions in groups of muscles, or in muscles not to be excited directly. A good example of the latter is the faradisation of the phrenic in the neck for stimulating the action of the diaphragm.

Faradisation of special organs will be found described in the special part under the different diseases where it is applicable. The various forms of electrodes necessary for this purpose are described elsewhere.

GENERAL ELECTRISATION.

Under this head we include central galvanisation, general faradisation, and electric baths.

Central galvanisation consists in bringing the whole cerebrospinal axis under the influence of the current. The negative pole being held stationary over the pit of the stomach or the sacrum, the positive pole is held first upon the forehead and vertex, then along the course of the sympathetic and pneumogastric in the neck, lastly, upon the cervical, dorsal, and lumbar regions of the cord successively. Here, as usual, a very exact graduation of current strength is needed during the application to the head and neck. Stronger currents may be applied to the spine without fear. The duration may extend to 2 minutes to the head, 4 to the neck, and 10 to the spine. Central galvanisation is indicated in cases of general nervous depression, of nervous insomnia, etc., and is useful as an adjunct to other modes of treatment.

General faradisation consists in sponging the whole, or the greater part of the body with the negative electrode, whilst the positive is held *in situ* on some insensitive part of the body, sternum, sacrum, etc., or fixed to a copper plate upon which the soles of the feet rest. The difficulty of the application lies in the proper regulation of the current necessary to stimulate fully, without causing actual pain,

the different parts over which the sponge is being carried. This will best be learnt by personal experience.

General faradisation by its action upon the muscular system promotes tissue change and nutrition. Any one who has experienced the refreshing effects of such an application will fully appreciate its value. It braces up the system, and promotes circulation, as evidenced by a rise of temperature sensible to the thermometer. The application is to last about 10-15 minutes, or longer, special attention being paid to the thorough stimulation of the muscles of the neck and back.

An easy method of practising general faradisation by the patient himself, is to put the positive wire in the water of an ordinary hip or other bath in which he sits, and connect his sponge with the negative. If the coil is not strong, salt water must be used. This simple application will be found a very useful substitute for the faradic bath, which, whatever may be its merits, is too complicated a process to find general acceptance.

The *galvanic bath* has been lately extolled for its virtues both as a tonic, and also as an eliminator of metallic poisons from the blood. Much has yet to be done before its efficacy can be established either theoretically or practically. Both galvanic and faradic baths consist in immersing the patient in an ordinary warm bath through the water of which the current is sent. One question obviously arises: how much electricity penetrates through the skin and actually passes through the body? This has never been answered by actual experiment.

Combined electrisation.—A curious blunder has been made by some electro-therapeutists, (see for instance Beard and Rockwell, l.c., p. 302) who recommend combined galvanisation and faradisation. They overlook the fact that electrical currents choose the path of least resistance, and that their currents instead of passing through the patient's body, circulate through the battery and coil used. A glance at the figure at p. 390 given by the authors just mentioned, will be enough to render the mistake palpable. The two batteries should be placed in series, so that the break induced have the same direction as the galvanic current.

Combined galvanisation and voluntary movement has been used by Dr. Poore in cases of writer's cramp, and deserves more extensive trial. In some cases where the stimulus of the will was defficient, I have tried galvanisation of the whole limb, and simultaneous faradisation of the individual muscles with apparently good results. The rationale of combined electrisation is, that under the catelectrotonic and refreshing influence of a galvanic current, nerve and muscle react more readily to stimuli, and can be worked longer without being tired. It is a good plan, in all cases, to have recourse to the refreshing effect of the galvanic current after the faradisation of a set of muscles. The full benefit of the enforced exercise is reaped without exposing the patient to the feeling of fatigue which is occasionally complained of, especially if the application has been somewhat too energetic or protracted.

Dr. Radcliffe's Positive Charge.

This method of electrisation has been proposed by the distinguished physician whose name it bears. Its rationale is intimately bound up with a peculiar theory of muscle and nerve, for which the reader is referred to Dr. Radcliffe's "Vital Motion as a Mode of Physical Motion." I shall confine myself here to the "modus operandi." An earth wire is attached to the negative pole of the battery, and the patient electrised in the usual way, that is, the two electrodes placed in contact with the diseased parts of his body. We are directed to insulate the battery and patient, by placing them on a thick piece of india-rubber cloth.

In the absence of sufficient clinical evidence, it would be premature to pass any judgment upon the therapeutical superiority of this method. Some observers report favourable results; and its adoption would by no means imply that of the physiological theories which have suggested it. Some remarks from a physical point of view are, however, required, as there seems to be considerable misapprehension as to the nature of the phenomena implied; and the point is of considerable theoretical interest. The name "charge" is somewhat misleading. It is not a charge in any other sense than ordinary galvanisation: for by charge is meant, simply the fact of a body being kept a potential, or potentials, different from that of the earth. A glance at the diagram illustrating the effect of an earth wire shows that by connecting the negative pole to earth, we merely effect a redistribution of potentials which become all positive, instead of being some positive and some negative.*

The use of insulating the battery and the patient is more than doubtful: we have to do with very low electromotive force (or "tension") indeed, seldom exceeding 50 or 60 volts, far too weak to overcome the resistance of the cells and wooden casing, or of the clothes and boots which are all very bad conductors.†

It is often said that the earth wire "carries off the negative electricity." This is a most clumsy, if not absolutely erroneous, explanation of facts. We have a certain point, N, charged to a given negative potential, and we connect it with a practically unlimited reservoir of elasticity at zero. What happens is simply this: enough of the earth's electricity is decomposed to reduce the potential of N to zero; the flow then takes place *from the earth to N*. Once N is reduced to O, that is to the same level as the earth, no more electricity can possibly flow from the one to the other.

An advantage claimed for the positive charge, is that the caustic effects of the negative pole are done away with; this is a confusion

* In an ordinary galvanisation the zero potential is at a point in the body about half way between the electrodes. If the positive pole is held in the right hand and the negative in the left, the right half is "charged" positively the left negatively, the zero being at the mesial line of the body.

† Even if the patient were to stand with naked feet on moist ground he would none the less be "charged" positively, only two points of his body would be at zero, viz., the soles of his feet, and the part in contact with the cathodes.

between "negative electricity" and "negative pole," which of course are completely different; the former is a mere theoretical assumption; the latter a reality. The cathodal effects are identical, whatever relations the potential of the point at which they manifest themselves bear to the earth's potential.

The diagram, fig. 7, illustrating the action of earth wires will make it readily understood, that in the plan advocated above, of introducing into the circuit a large rheostat resistance and increasing the number of cells, the patient is "charged" with positive or negative electricity, according as the rheostat is connected with the negative or positive pole respectively. Suppose a circuit of the total resistance AB of which a part of the human body A a, makes about one eighth (3000 ohms) and a rheostat a B, seven eighths (21,000 ohms), the rheostat being interposed between the body and the negative pole of a battery with an electromotive force equal to AB + DE. Then the zero potential will be at the point o in the rheostat, and the body "charged" to potentials measured by the ordinates of the points along A, a, (AC, etc.)

It will be seen that by this method, not only patients are "charged positively," but that they can easily be made so to far higher potentials than with the earth wire method, where the number of cells cannot be made large enough, without unduly augmenting the current-strength.

Though I have now been sometime in the habit of using rheostat resistances in medical applications, and thus of "charging" the patients, I am not conscious of having obtained any better results on that score. As a matter of fact I have used the rheostat so as to "charge" positively sometimes, negatively at other times, without having observed any special advantages of the positive over the negative charge.

CHAPTER V.

TREATMENT.

SENSORY NEUROSES.

Neuralgia.

Faradism.—Two general methods can be adopted in the treatment of neuralgia. The first, called hyposthenizing, consists in using a very strong current, with very rapid intermittences. The extra-current must be used, and wet electrodes are to be placed, the positive on the point of the nerve nearest to the centres, the negative upon the painful branches of the nerve.

It is evident that after a while such a current must diminish the excitability of the nerve, and extinguish the pain; at first the pain is very acute, but is soon followed by a feeling of numbness which gradually increases until it is complete. After the application the nerve recovers gradually its excitability, and, as is usually the case, the pains may reappear.

The second method, called revulsive, consists in faradising the skin. Either the metallic brush is energetically used, or the solid metallic electrodes are applied over the painful spot, with very rapid intermittences. The current must be graduated according to the strength and sensitiveness of the patient. The operation lasts 5-8 minutes. This treatment sometimes gives good results, and can be explained physiologically: we know that the electrisation of the sensitive nerves determines a more active flow of blood; and as neuralgias are usually accompanied by modifications in the capillary circulation it follows that the augmentation and acceleration of the flow of blood may lead to the removal of the painful symptoms. These two methods have the disadvantage of being very painful, and may offer some danger on account of the violent excitation they produce. We therefore believe that in nearly all cases of neuralgia it will be better to use the galvanic current.

Galvanism:—Very constant currents of moderate strength are to be preferred. The skin is not to be excited. Broad electrodes wetted with simple water are therefore to be used; and the mode of application will vary according to the kind of neuralgia to be treated.

Facial Neuralgia.

We place the negative pole over the point 1 in figure 94, and the positive at the periphery on the painful branch: at 4 when the frontal branch is affected (a case frequently mistaken for megrim); at 2 and 3 where there is neuralgia of the supra or infra orbital branch; and over the course of 7 when the dental nerves are also

affected. In these various cases a current of 6 mv. (10-12 El.) is used, the electrodes being held immoveable for 6-8 minutes.*

Tic Douloureux.

In this disease the positive pole (which must be a rather narrow electrode) is held over the points of exit of the nerves, 2 and 3, and the negative pole over the cervical ganglion, (10, fig. 94). The strength of current and time as given above. When the movements of mastication call forth violent pains, the negative pole must also be held for 2 or 3 minutes over the masseter. When a cure is to be effected, the amelioration begins after the very first sittings; and sleep, often disturbed or impossible to the patient, returns; this is a good sign, auguring a definitive cure.

We must add that frequently the disease is due to a central cause, and then a cure is very rare. In 6 cases we have had the opportunity of treating, success has been obtained in 2 only.

Occipito-cervical Neuralgia.

Positive pole on the nape of the neck, over the upper cervical vertebræ, and the occipital nerve (9, fig. 94); negative pole held in supra-spinous fossa. Current strength, 6-8 mv. (from 10-25 El.).

Cervico-brachial Neuralgia.

With excitable patients the same current as above must be used; in other cases the strength may advantageously be increased to 12 mv. (35 or 40 El.). The positive pole is to be held over the cervical vertebræ, and the negative placed in the axilla, or lower down at the level of the elbow, if the neuralgia extends into the forearm. According to the seat of pain it will be easy to tell which nerve is affected, and the electrode must also be applied to the points (1 and 2, fig. 95) where the nerves are most superficial.

Intercostal Neuralgia.

The positive pole is placed over the point of emergence of the diseased nerve behind; and anteriorly the negative must be held in the intercostal space along which the nerve runs. Current of 8-10 mv. (20-35 El.). With fat patients a stronger current may be used in this as in the preceding neuralgia, especially at the begin-

* With reference to the unit of quantity here used, I need only refer the reader to what has been said in pages 6 and 20. The milliveber (mv.) is to the physician one subdivision of his galvanometer, as the degree is one subdivision of his thermometer. I have preserved, however, in the text the indications given by Dr. Onimus in elements (El.) for the convenience of those who are not prepared to adopt the more exact method. The elements here referred to are always the sulphate of copper or Daniell's cell, the electro-motive force of which may be taken as 1 volt. When Leclanchés are used, it will then be necessary to take a proportionally smaller number, *i.e.*, 2 Leclanchés for 3 Daniells. Of single fluid elements the Smee must be considered somewhat weaker than the Daniell, the Stöhrer stronger, though it is difficult, owing to their inconstancy, to give any but approximate determinations. 5 Smees (3 Stöhrers) are equal to about 4 Daniells. The chloride of silver cell may be considered as equal to the Daniell. The internal resistance of the elements here used may be taken at 20 ohms.

ning of the sitting; but towards the end, the current must always be gradually diminished, and localised near the nervous centres.

In older neuralgias, and where the pain is not well localised, a few interruptions may be made at the beginning of the sitting, and the skin excited by drawing the negative rheophore over the surface (labile current). But towards the end, again, any sort of interruption must be avoided.

Lumbo-abdominal Neuralgia.

The positive pole being held a little outside the upper lumbar vertebræ, the negative is placed over the middle of the iliac crest if the pain is confined to the posterior region; but if it extends more anteriorly, as far as the scrotum or vulva, the negative pole must be placed in that region. Current of 10 mv. (20-40 El); duration, 10 minutes.

Sciatic Neuralgia.

Faradisation has been used sometimes with success in sciatica; but generally the violent excitation produced by the methods above described, so far from diminishing the pain, only increases it.

We always use galvanism in this way: the positive pole is placed over the sciatic notch, and the negative over the course of the nerve, so that the painful points be included between the two poles. During the latter part of the sitting, the positive pole is to be placed higher up, over the lumbar vertebræ and the negative successively on the points 1, 1, fig. 98. If, as is often the case, pain extends along the peroneal nerve, the negative pole must also be held over the nerve at the point 2 below the popliteal space. A current of 10-15 mv. (25-50 El.) is to be used according to the tolerance of the patient; the duration to be from 12-15 minutes.

If the pain be not too great, it will be useful to make a few interruptions, or even voltaic alternatives. But this is to be done only in the middle of the sitting, and during the last part of it no shocks are to be given.

Uterine Neuralgia.

Certain neuralgias, when occurring in women, present at once symptoms of a more general state; these so-called hysterical neuralgias are often the result of a constitutional disturbance. In some cases, however, they are not the result but the cause, or at any rate keep up the hysterical state; they then must be treated independently. The most important neuralgias of this kind are those of the neck of the uterus, and of the parts around. In such cases the galvanic current has a very beneficial influence. It is not indispensable to apply the current to the uterus itself; the electrisation of the lower part of the spinal cord has given us excellent results. For this purpose the positive pole is placed over the tenth dorsal vertebra; the negative over the sacrum. Begin with a current of 5 increased to 10 mv. (15-30 El.); duration, 8-10 minutes.

In some cases, however, especially if one of the ovaries is the seat of the disease, we must act locally. One of the poles, gene-

rally the positive, is placed upon the cervix, and the negative upon the walls of the abdomen over the painful ovary. Duration, 4-6 minutes, beginning with a weak current of 4, which may usually be gradually increased to 10 or 12 mv. (10 to 30 El).

Vesico-Urethral Neuralgia.

This is one of the rare cases of neuralgia for which it is difficult to give precise indications as to the direction of the current to be used.

We usually place the negative pole over the spine at the level of the sacral plexus and the positive over the pubes and the perineum. Current of 8-12 mv. (20-40 El.). Several conditions are to be taken into account, and especially the sensitiveness of the skin in the perineum. This is one of the reasons why we apply to it the positive pole, which is less painful than the negative.

In vesical neuralgias accompanied by spasms and contractions, if no result be obtained from external electrisation after a few sittings, a small electrical sound must be introduced into the bladder, and connected with the positive, whilst the negative is held externally over the pubes. Here we must always use a moderate current of 5 or 6 mv. (15-20 El.) and never beyond 3 or 4 minutes. Care must be taken not to use too large a sound, and not let the current flow whilst it passes through the urethra.

Megrim.

We have used two methods equally successfully in the treatment of this disease. The first consists in placing two electrodes, one on each side of the forehead, with a current of 3 or 4 mv. (8 El.) at most, during 6 to 10 minutes. The second, which we generally adopt, is to place the electrodes below and behind the mastoid process on either side, at the point 10, with a current of 5 or 6 mv. (10-14 El.)

Ancient Neuralgias, and Consecutive to Neuritis.

Here there is always a more or less marked organic lesion. Hence it is plain that a much longer time will be required to cure them. Recovery can take place only when the alterations in the nervous tissue have been arrested and modified. We must therefore act chiefly upon the nutrition of the tissues, and neglect the element of pain. Galvanism is then to be preferred; but it may be useful at the same time to apply a faradic current, with slow intermittences, to the muscles which suffer from incipient atrophy. This must be done at the beginning of the sitting. The galvanic current is next applied, the positive pole being held over the central origin of the nerve and the negative passed over the points where it is superficial at the peripheral, and over the muscles affected. A rather strong current (10-12 mv.) must be used, and a few interruptions are to be made.

This treatment will usually effect a cure, as our experience has

taught us, whenever the neuralgia and neuritis are not symptometic of other affections; here indeed our results have been remarkably constant and successful.

Cutaneous Anæsthesia.

This case depends upon various causes, and generally accompanies diseases of the nervous centres. In this case the treatment must be directed to the disease of which the anæsthesia is a symptom.

The peripheral causes may be a traumatic lesion; compression by a growth or exudation; defective nutrition of a nerve; a previous neuralgia; a diminution of circulation; prolonged exposure to cold. This last cause is perhaps the only one which gives rise to an anæsthesia limited to the distribution of a sensory nerve without any other complication of motor or central nature. This form of anæsthesia is chiefly met with in persons who have their hands almost constantly in cold water, such as washerwomen.

In the latter cases faradism, especially applied with the wire-brush, is to be used. In the other forms of anæsthesia galvanism is preferable and less painful. A current of 12 or 15 mv. (40-50 El.) is to be used when the limbs or trunk are the seat of the disease. The current must in all cases be ascending, that is the negative pole must be applied over the central origin of the nerve and the positive over the peripheral seat of the anæsthesia. If for instance the ulnar nerve is affected (the most common instance) the negative pole is placed on the nape of the neck and the positive at the elbow, and drawn along the course of the nerve (2, 2, fig. 95) at the inner side of the forearm.

Facial Anæsthesia.

It occurs as a rule after, as a sequela of neuralgia but may also be caused by traumatism (blow, fall, or cold). Faradism is always dangerous to use here on account of its exciting effects upon the neighbouring centres. Galvanism on the other hand offers no such risk, even when a strong current is used. A strength of 6-8 mv. 10-14 el.) however is sufficient, the negative pole being placed over 1 or 10 and the positive over 5, 6, 7, fig. 93. The electrode is also to be passed lightly over the whole of the anæsthetic surface, care being taken however to avoid sudden interruptions.

MOTORY NEUROSES.

Tic Convulsif, or Histrionic Spasm.

This affection is not very rare, and may be limited to one or more branches of the facial. When limited to the palpebral branches, it gives rise to more or less rapid contractions in the upper lid, or to a complete closure of the eyelids. It then receives the name of blepharospasm and is the most common instance of the disease.

In most cases of tic every treatment is powerless. Faradism is

entirely contra-indicated. Galvanism often produces a great improvement; but unfortunately this frequently is but temporary.

We have, however, obtained very satisfactory results relatively speaking, and have noticed that such results were usually obtained in cases where the compression of the facial nerve suspended, for the while, the spasms. We apply a centripetal current of 6 to 10 mv. (12-15 El.) during 5 or 6 minutes. Positive pole on 5, 6, 7, 8, and negative on 1, fig. 94.

Spasms of the Neck Muscles.

The trapezius and sterno-mastoid (f), and often the second only, are most commonly affected. The spasm is usually tonic and unilateral. We have no instance of the complete cure of this disease either by galvanism or faradism. Considerable relief, however, is given by an ascending current of 8-10 mv. (20-30 El.), the negative pole being placed over the nape of the neck, the positive over 10 or 13, fig. 94.

Cramps.

These are painful muscular contractions, but of short duration, occurring spasmodically in certain people whose general health, however, is otherwise satisfactory.

These cramps usually affect the flexor muscles of the limbs, chiefly of the legs. They occasionally occur in trunk muscles and thus seem to constitute real neuroses. A current of 8-10 mv. must be used (20-30 El.), the positive pole being placed over the central origin of the nerve, and the negative passed over the painful muscles.

Writer's Cramp.

This disease usually appears in people who have much writing to do, and here it is difficult to cure or improve. Sometimes very nervous people are affected, though they do not write much. The same form of disease is met with in draughtsmen, engravers, telegraphists, violinists, &c.

We have had a few cases of improvement; but this disease is most obstinate. If there are at the same time paretical symptoms, a cure is more easily effected. This is the method we follow: For 10 minutes the negative pole is placed on the nape of the neck and the positive over the muscles of the forearm, especially those of the thumb; current of 10-12 mv. (30-40 el.) Then a moderate current of 6-8 mv. is sent upwards through the cervical portion of the cord. This is repeated every other day. During the treatment the patient must give up his usual occupations, and on the other hand exercise the muscles habitually little used.

Contractures of the Extremities.

In these affections there is increased excitability of the motor nerves, whilst that of the sensory nerves is diminished. Descending currents, during their applications, augment the contractions. The best plan is to send a weak ascending current of 3 or 4 mv.

(10-12 El.) through the upper part of the spinal cord. The same method is to be followed when the contractures are due to traumatism. Any muscular fatigue is to be avoided.

Tetanus.

Galvanism, from experiments made upon animals, has always been thought likely to do good in tetanus. Applied to the patient their effect is first to cause relaxation of the contracted muscles, and thus to procure much relief to the patient. Chloral, which may be administered at the same time with advantage, calms the patient, sends him to sleep, but does not prevent the contractions as the current. It must be applied *descending along the cord*, the positive pole being on the cervical, the negative over the lower lumbar vertebræ. Its strength must be moderate, weak rather than too strong, 5 or 6 mv. (15-25 El.) It must be continued for longer periods than in the other cases; and must be very constant, the electrodes being not too often moved.

Chorea.

Faradism has no influence over chorea; and may even, according to some observations, increase the movements.

On the other hand galvanism is, beyond all doubt, efficacious. We have seen this disease give way to 5 or 6 applications of the current. Experience has proved that the ascending current, notwithstanding its greater exciting influence, or perhaps on account of it, has a more marked effect than the descending. It may be applied to the cord only, or to the cord and limbs. Duration 10-15 minutes; strength, 4 to 6 mv. (10-25 El.) for the cord, 10 or 12 mv. (30-40 El.) for the limbs, according to the tolerance of the patient. As a sequela of chorea there occur sometimes paralyses of the affected limbs; here galvanism is of the greatest use. A descending current is to be used; the positive on the cervical vertebræ, the negative pole on the paralysed muscles. At the beginning of the sitting some interruptions must be made, and the electrode drawn along the course of the motor nerves.

Paralysis Agitans.

A rather strong current of 10 to 12 mv. (30-40 El.) is to be applied to the spine, the negative pole being held on the sub-occipital region, and the positive over the lower cervical vertebræ and cervical ganglion, 10. If the paralysis be localised in one of the upper extremeties, we also place for a few minutes the positive pole on the brachial plexus, and the negative on the nape of the neck. Considerable improvement may follow, but we know of no cases of complete recovery. Faradism must never be used.

Generally speaking, the pathological facts prove that in these chronic affections the galvanic current has given excellent results, and is one of the most efficacious and least dangerous of therapeutical agents. If the disease is recent, a complete cure may be

effected; and in the immense majority of cases, the progressive advance of the disease may be arrested, often for a considerable time.

Epilepsy.

Electricity has often been used for the treatment of this disease, but almost always without any marked result. It must be used only to oppose certain symptoms which occasionally accompany it, such as tremors, pareses, contractions, etc. The treatment will be the same as described under these heads, but care must be taken to avoid strong currents and interruptions.

In certain forms, however, where slight epileptoid seizures occur, dependent upon a modification of nervous irritability, or of cerebral circulation, fair results may be expected from stimulation, by means of the faradic current of the peripheral nerves connected with the centres affected. Moderate galvanisation of the sympathetic may at the same time be resorted to.

Catalepsy.

In this disease, if not absolutely curative, electricity is most beneficial in drawing the patient out of the lethargic state into which he is sunk. Faradism may be used to cause contractions of the respiratory muscles, and to produce a sort of artificial respiration, or as a general stimulant.

Galvanism must be applied directly to the nervous centres, as in cases of syncope or asphyxia. Under the influence of this application, respiration becomes gradually deeper, and the heart beats more vigorously. We have seen in a cataleptic woman the contracted muscles to relax during the passage of the current. On galvanising the cervical cord and pneumogastric nerve, the increased rapidity of the respiratory movements, and still more the greater energy of the cardiac contractions, became very evident. The hibernating animals, when in the state of torpor, can be aroused for the rest of the winter by the current from 8-10 Daniells' cells.

PERIPHERAL PARALYSES.

Paralyses following Compression or Contusion.

When paralysis is due to the compression of the nerve, electrical treatment is to be used only when the cause of the compression has been removed. But then, even if the nerve is profoundly altered, it is always followed by most satisfactory results. In such cases there is always more or less muscular atrophy. The treatment must therefore embrace both nerves and muscles. Galvanism will be used for stimulating the general nutrition, and especially for recalling the excitability of the nerves; faradism to promote the functional activity of muscles. In using galvanism, the positive pole must always be placed upon the cord, or at least above the seat of the lesion and the negative over, or a little below that seat

so as to comprise the diseased portion between them. According to the cases a current of 10-15 mv. or more, (30-60 El.) may be used. The muscular atrophy being almost always simple, the faradic current may be advantagiously applied locally.

Simple contusions, dislocations, especially of the shoulder, can produce peripheral paralysis, and consecutive muscular atrophy. The same treatment as just described must be applied. Especially at first the interruptions of the induced current must be slow.

Paralysis of the Motor Nerves of the Eye.

These paralyses are frequently the sign of a central affection either of the brain (tumour, hæmorrhage) or of the cord (locomotor ataxy). Sometimes, however, they are idiopathic; and then a cure is usually obtained in a comparatively short time. For this purpose a current of 7 mv. (8-10 El.) is used, the positive pole being near the eye-ball, the negative on the temple of the same side, or over the cervical ganglion. Duration, 5-6 minutes; two or three sittings every week.

Paralysis of the Facial Nerve.

We describe elsewhere the method of discovering whether the paralysis is of central or peripheral origin. When peripheral, that is due to the effect of cold or pressure, a usually rapid cure is almost certainly obtained by means of the galvanic current. Strength, 8-10 mv. (15-20 El.); the positive pole is placed in front of the ear, (at 1, fig. 94) and the negative on the several muscles, *a b c d.* Some interruptions are to be made upon each of these muscles. Duration, 5-8 minutes every day, or other day. It is better not to use the faradic current during the first period of the disease.

Paralysis of the Musculo-spiral Nerve.

Rheumatic paralysis of the musculo spiral nerve is often observed, but in different degrees. If the cause be due to circulatory disturbances, and the vascular phenomena be easily restored to their normal state, every agent which acts directly upon the circulation may bring about a cure. Thus blisters, cold douches, frictions even, may in slight cases result in a cure. If the vascular perturbation be deeper, and if the excitability of a portion of the nerve be completely gone, the ordinary revulsives remain powerless, and no treatment is likely to be successful except the electrical current.

We use here a current of 10-15 mv. (30-50 El.) placing the positive pole upon the brachial plexus, and the negative upon the affected nerve, anteriorly along the internal border of the supinator longus muscle (e-e, fig. 96). Each sitting is to last about 10 minutes.

When muscular atrophy is present, along with paralysis, faradism may be simultaneously applied to the affected muscles, whilst galvanisation is carried on as above described. The interrupted galvanic current may however be used instead of the faradic; the two electrodes are then applied to the extremities of the muscles which are so made to contract.

Paralysis of the Anterior Tibial.

Both currents are to be employed simultaneously; or the galvanic alone with interruptions as just described. The positive pole is placed in the popliteal space, and the negative on the ancle, at the external border of the tibialis anticus tendon. After 5 or 6 minutes of such an application the muscles are made to contract singly by means of the faradic or interrupted galvanic current.

VARIOUS NEUROSES.

Hysteria.

Electrisation will be found of but little avail for the general disease; but excellent results may be obtained from it in the treatment of many of its hysterical phenomena, especially paralyses, contractures and anæsthesia.

Paralyses. It is best to act simultaneously upon the nervous centres and paralysed muscles. For this purpose a current of moderate strength is to be passed down the spine; and at the same time the muscles are to be submitted to a kind of artificial gymnastics, either by a rapidly interrupted galvanic, or a faradic current. The intermittencies of the latter must not be too rapid; and it must be applied to the limbs only, and never near the nervous centres.

Anæsthesia. In cutaneous anæsthesia, faradisation is superior to galvanisation, and is successfully practised by means of the electric brush.

Contractures. Galvanisation of the spine must be resorted to, with a rather mild current of 5-8 mv. (15-30 El.) but giving sittings of longer duration. In such cases permanent currents may be used successfully, a current of 1 or 2 mv. (4 or 5 El.) being used for an hour or two, instead of applying a stronger current for a quarter of an hour. Individual sensitiveness to electrical applications must, however, always be taken into account.

The direction of the current is not so easy to determine in hysterical paralysis and contractions as in other affections. In a general way, however, it is better to begin with the more sedative descending current, and try the ascending later on.

At the end of the sitting we cautiously galvanise the sympathetic; and when the symptoms are variable and momentary it is the only mode of electrisation we employ.

The successes obtained by this method are often very rapid; and if after a few sittings no progress is made, or if a stationary stage is reached after some improvement has been obtained, the treatment must be suspended for a few weeks and then resumed.

Angina Pectoris.

Duchenne relates two cases where he has been able not only to arrest completely and instantaneously an attack of angina, but also to retard the progress of the disease and perhaps even, he says, completely to cure it.

In these two instances he applied *loco dolenti*, that is under the left nipple and at the upper part of the sternum, the extremities of two wires connected with his faradic apparatus working at its maximum intensity and rapidity. This is an application of the electro-cutaneous method used in neuralgia. But, as he himself remarks, it is impossible to conclude from these two isolated cases a general mode of treatment; and it seems to us that such a violent stimulation of the precordial region is not without danger.

Exophthalmic Goitre.

In our cases of Grave's disease galvanisation has given good results. Most frequently we have arrested the progressive development of the disease; and often have obtained a considerable diminution of the severity of the symptoms, so much as to enable us to consider the patient practically cured. We use a current of 2-8 mv. (5-20 El.) during 8-10 minutes, applying the electrodes on both sides of the neck at the level of the cervical ganglion, 10.

DISEASES OF THE NERVOUS CENTRES.

Hemiplegia.

Two periods must be distinguished in cases of cerebral hæmorrhage, with regard to the use of electricity.

In the first period, about a week after the attack galvanisation may be resorted to. The positive pole is placed on the forehead, on the side of the lesion, and the negative on the nape of the neck, and a current of 3 or 4 mv. (6-8 El.), is allowed to pass during 2 or 3 minutes. The sympathetic is then galvanised for 5 minutes with a stronger current of 6 mv. (10-12 El.) It is indispensable to begin the sitting with the minimum current strength only, and augment it only gradually. The same precautions are to be taken to finish gradually. The resorption of the clot will thus be promoted by acting moderately upon the cerebral circulation; and this treatment will also be found useful in cases where the hemiplegia is due to an obliteration of the vessels, or pressure due to stasis in the vessels.

In the second period, that is a few weeks after the beginning of the disease, both the sympathetic and the limbs are galvanised. For the latter, the positive pole is placed on the spine, whilst the negative is slowly drawn over the limb. Current, 10-12 mv. (30 to 60 El.) for 10-15 minutes every day or other day. After a few sittings some increase of the movements is almost always obtained. When the lesion is considerable, and the limbs contracted, the restoration of motion cannot be hoped for; but it is possible in these cases to calm the pain if it exists, and momentarily relieve the contractions. There is no advantage to be derived from faradisation; if however the induced current were used, the muscles of the limbs only should be acted on, and the intermittences should be very slow.

Spinal Irritation.

This name has been given to a collection of symptoms, such as pain along the spine, especially on pressure upon the spinous processes, with various irradiations, and of different kinds of functional disorders remarkably mobile in their manifestations.

Galvanism has been very useful in our hands; in some cases 6-8 sittings have been sufficient to effect a cure. The positive pole is placed upon the cervical vertebræ, and the negative upon the lumbar or sacral region, below the tender spots. A currrent of 10 mv. (30-40 El.) is to be used for 10-12 minutes each time. During a part of the sitting the positive pole may be drawn slowly along the vertebræ, but without any interruption.

Myelitis.

Though electricity has a decided influence over the circulation and the inflammatory phenomena, it would be imprudent to employ this agent in the acute diseases of the nervous centres; at any rate whenever they are accompanied by an intense fever. As soon, however, as the disease loses its acute character, it is advantageous to use the current, and as much as possible apply it to the spine itself. Much prudence is needed, however, and a very constant current is required, and no shocks must be given. A sedative effect being sought the current must be descending, and of a strength of 8 mv. (20-30 El.).

In chronic myelitis a descending current of 10 to 15 mv. (30-60 El.) may be employed, and during part of the sitting the positive pole may be left on the spine whilst the negative is held on the limbs.

Locomotor Ataxy.

Experiments made upon a large number of patients have shown us that a great improvement may be obtained in most cases from galvanisation, and that often the disease appears to be arrested in its progress. But here more than anywhere else it is important to consider the direction of the current to be used and the region of the body to be acted upon. Galvanisation of the limbs is, to say the least of it, useless; it is the spinal cord which is to be treated. It is important to use an ascending current, that is the positive pole over the lumbar, the negative over the cervical, vertebræ. If this rule is not followed one frequently sees the pains in the limbs reappear or even increase. A current of 10 mv. (30-40 El.) is to be used, for 10 minutes at most. The most appreciable effects are a diminution of the pains and an improvement of the bladder. Where there is considerable weakness of the legs, with tendency to muscular atrophy a descending current may be tried, the positive pole being placed upon the dorsal, the negative to either side of the lumbar vertebrae. Even in these cases, however, it is never necessary to act upon the peripheral nerves of the leg. During the congestive periods all electrisation must be carefully avoided.

Infantile Paralysis.

The treatment is to consist in the moderate galvanisation of the parts of the spinal cord, whence start the nerves supplying the paralysed limbs, as well as of the limbs themselves. This is how we usually proceed: we first pass the electrodes over the affected muscles, making a few interruptions; then we place the positive pole on the spine, and the other on the course of the nerves of the part affected; lastly, in order to influence the circulation, and remove the excitation which may have been produced, we apply a current of 6-8 mv. (10-25 El.) during two or three minutes to the cord itself. The sittings to be repeated every other day, and to last 10-12 minutes.

After a few weeks it is well to suspend the treatment for a fortnight or a month, during which time other therapeutical means are carried on, such as sulphur baths, frictions, etc.

The more recent the attack, the more favourable the prognosis; and we believe that the use of the current as soon as the acute stage has disappeared, that is 8-10 days after the first symptoms, yields the most satisfactory results.

At this early period it is necessary to act upon the cord only with a weak current of 5 or 6 mv. (10-15 El.) and then gradually to extend treatment to the nerves of the limb.

It is also useful to apply the faradic current to the muscles. But here especially we recommend the use of currents with slow interruptions only. The current given by the ordinary faradic apparatus are very bad; they merely excite the sensory nerves, greatly excite the child, without much profit to the muscles themselves. Every day one hears parents complaining of the over-exciting action of faradism upon their sick children. This is owing to the fact that unsatisfactory apparatus is used. On the other hand, even delicate children bear very well strong induced currents, when the intermittences are few and far between. As to galvanism, if properly applied, they bear it almost more easily than adults, and experience from it neither pain nor excitement.

Spinal Paralysis of the Adult.

Here we use a descending current of 10-12 mv. (40 El.) down the cord; and, in addition, to prevent muscular atrophy, we act upon the limbs with induced or interrupted galvanic currents, as in cases of progressive muscular atrophy.

Spinal Meningitis; Pachymeningitis.

Galvanisation has given us good results in this disease. We apply to the spine a descending current of 10-12 mv. (30-50 El.) the positive pole being on the upper cervical, the negative over the lower lumbar vertebræ. Duration, 10 minutes.

Progressive Muscular Atrophy.

In the treatment of this affection, the cord only is to be galvanized during the first part of the sitting with a current of 10 mv.

(30-40 El.); then during 5-10 minutes, the positive being on the spine, place the negative pole upon the plexus, or nerves of the diseased muscles. Then the negative pole is to be passed for 5-6 minutes over the muscles themselves, with interruptions. Faradization may be used for the muscles; but then the applications must be short, and the intermittences very slow.

PARALYSES FOLLOWING ACUTE DISEASES OR INTOXICATIONS.

Saturnine Intoxication.—Abdominal Myalgia.

Lead palsy is a common disease. The treatment must consist in the application of a descending galvanic current to the cord; and of an interrupted galvanic current to the attacked muscles. These may also be faradised strongly. If there is any colic, galvanization of the coeliac plexus, placing the positive on the cord, and the negative on the pit of the stomach will soon subdue the intense pain. A current of 10-12 mv. (40 or 50 El.) may be used.

Many cases of abdominal myalgia have been relieved by cutaneous faradisation, *loco dolenti*. Most acute attacks have been cut short by this mode of treatment. The symptom only is modified, however, and the disease itself subsists, and renewed attacks of pain may occur which are not amenable to the same remedy. Thanks to the anodyne and sedative influence of the galvanic current, fresh attacks may be prevented. A descending current of 8-10 mv. (30-40 El.) is to be applied to the diseased muscles, taking care to pass the current in the direction of the fibres. Thus, if the rectus abdominis has to be treated, the positive pole is to be placed upon the xiphoid cartilage, and the negative over the pubes; if the external oblique, the positive on the side at the level of the last ribs, the negative in front upon the lower part of the abdomen. Duration, 10-12 minutes.

Sequelæ of Acute Diseases.

In all paralyses following eruptive fevers or other acute diseases galvanisation of the cord and sympathetic must be resorted to.

According to the nature of the case, and if undue excitement has not to be feared, it is better to use ascending currents. They give greater impulse to the general nutrition, which is deficient; they stimulate the nervous functions; provoke molecular changes in the tissues, and arouse and strengthen the organism.

Diphtheria.—One often observes as sequelæ of this disease paralysis of the soft palate; and loss of mobility and sensibility of the vocal cords, which produce suffocative attacks, especially during the act of drinking, and alterations of the voice. This state may be very persistent unless remedied.

Paralysis of the soft palate yields equally to faradism and galvanism. Galvanisation is practised by placing exteriorly on either side of the larynx the rheophores, and using a current of 10 mv. (15-20 El.).

Galvanism has an almost specific action upon the muscles of the larynx; for it is in them that "galvano-tonic" contraction is best observed, that is, a semi-contraction during the whole time of passage of the continuous current. In cases where the voice, and especially singing, are modified after fatigue or excessive efforts of the larynx, we have obtained good results from the use of constant currents applied externally. The vocal cords thus recover their tonicity and physiological action.

Faradisation may be performed either indirectly by cutaneous stimulation, or directly by the application to the muscles of a laryngeal electrode, the other pole being placed externally at the level of the tria-thyroid muscle. In this case it is best to use a current with slow intermittences.

Typhoid fever.—This and other acute diseases have sometimes as sequelæ contractures of the flexors of the legs. These sometimes pass away spontaneously, but usually lead to serious infirmities. Galvanisation generally yields excellent results. If the flexors of the thigh upon the pelvis be contracted, a descending current of 8 mv. (20-25 El.) must be sent along the course of the crural nerve (1, 1). During a few minutes the positive pole must be held upon the lumbar vertebræ, the negative upon Scarpa's triangle; then the positive upon the triangle, and the negative on the inner and inferior part of the thigh. If the flexors of the leg are contracted, a descending current along the sciatic nerve is to be used, the positive pole being held over the sciatic notch, the negative first in the popliteal space. next behind the external malleolus. After 7-8 minutes of this application, the muscles of the anterior region of the leg (*a* to *d*) must be galvanised also, some interruptions being made so as to excite contractions.

Cholera.—The painful cramps tormenting most choleraic patients are most successfully treated by galvanism. A descending current of 8 mv. (20-30 El.) or more, is sent through the muscles during 5 or 6 minutes. The pains rapidly decrease, and rest is given to the patient. Whenever cramps recur the application must be removed.

Cholera frequently has sequelæ such as paralyses, or even atrophies of certain muscles, especially in the lower limbs. The nutrition must be promoted by means of the galvanic, and the muscles exercised with the interrupted galvanic, or faradic current.

These indications equally apply to paralyses consecutive to eruptive fevers, such as scarlatina, variola etc.

DISEASES OF THE MUSCLES.

Muscular Fatigue.

The protracted contraction of a muscle produces in it a certain degree of rigidity, and thus renders its further use difficult and painful. Usually after a few hours rest this rigidity disappears; but if the same muscle is frequently submitted to a too violent or protracted exercise, there occurs a state of permanent rigidity,

called muscular fatigue. The treatment of this often very painful affection consists in simply sending through the muscle a descending current of 12 mv. (30-40 El.) for four or five minutes. After the first application there is a marked amelioration, and a complete cure soon follows on repeating it a few times.

CONTRACTURES.

Contractures may be due to permanent irritation of a motor nerve, or to the want of circulation in the muscles.

It is evident that the faradisation of the affected muscles can only excite them still more. Duchenne recommended the faradisation of the antagonists. This method gives sometimes good results, but is not in any way preferable to galvanisation, which, in our opinion, is decidedly the best mode of treating contractured muscles. Galvanism augments the circulation without exciting contractions, and diminishes the irritability of the nerve, where this is the cause of the disease. A descending current of 12 mv. (30-40 el.) is used along the nerve and muscle for 10-15 minutes.

MUSCULAR RHEUMATISM.

Faradism often gives good results. It is especially applied with the brush over the painful muscles. But this is a painful process; and frequently enough the pains reappear after the first effect has passed off.

Galvanism is less painful and acts more powerfully upon the local circulation; in addition it has the advantage of counteracting the reflex phenomena of contracture in the muscles.

We must, in muscular rheumatism, use the labile method, applying the positive pole on the course of the nerve supplying the muscle, and the negative pass over the whole muscle itself, with a strong current of 12-15 mv. (40-60 El.). At the end of the sitting the current must be diminished, and the current allowed to flow continuously through the nerve and muscle for a few minutes. In lumbago for instance we first place the positive pole upon the dorsal region, to the right or left of the spinous processes and the negative pole is passed up and down the sacrolumbar muscles. After 5-6 minutes of this application, both poles are left immoveable for the same length of time.

MUSCULAR ATROPHY.

In simple muscular atrophy due to want of exercise or to altered nutrition resulting from inflammatory processes in the neighbourhood, faradism applied directly to the muscles is better than galvanism. Indeed it is in such cases that faradisation is preeminently indicated. Each muscle is to be faradised independently, and the intermittencies must not be too rapid.

When, however, the atrophy depends upon a central or peripheral nervous affection, galvanisation must be resorted to. A labile current of 12 mv. (30-40 El.) is then to be applied to the cord downwards, or to the nerve, according to the seat of the

lesion. During the latter part of the sitting, which is to last 12-15 minutes, the electrodes must be applied to the muscles themselves, and interruptions made so as to cause contractions.

Club-foot.

Electrical treatment is very useful here as it restores tonicity to the relaxed muscles, whose weakness may be considered as a main cause of the deformity.

Club-foot is almost always due to a disturbance in the functions of the muscles, be it paralysis or atrophy, be it contracture, of some one, or more, of them. Contractures are rarer than atrophies and almost always depend upon cerebral affections. The muscles most usually diseased are the tibialis anticus, the extensor pollicis, and the peronei. The electrodes of the induction current must therefore be placed on *a*, *a*, fig. 99 for the tibialis, on *b*, *c*, *d*, for the extensor and peronei. As much as possible slow intermittences must be used; the skin is to be well moistened, so as to avoid irritating the cutaneous nerves. As this treatment generally applies to children it is important not to produce any general excitement; and then good results are sure to follow.

If on the contrary the flexor muscles are affected, the rheophores must be applied to the points *e*, *f*, *g*, and a moderate current used.

Galvanisation must always be carried on *pari passu*; the positive pole must be placed upon 1, or upon the lumbar vertebræ, and the negative pole upon the atrophied muscles.

It is impossible here to speak of the varieties of club-foot; but in a general way it may be said that, in addition to the use of proper instruments, the main point is to fix upon the defective muscles, and frequently submit them to the action of both currents.

In the case of contractures, however, galvanism alone must be used. The strength of the current must be suited to the age and sensitiveness of the patient. Children bear galvanic currents, even strong, admirably, if but few interruptions are made.

DISEASES OF THE DIGESTIVE ORGANS.

Gastralgia.

This term has been used to designate disorders of the stomach of very different kinds, but should be confined to a nervous disorder, with symptoms of pain, more or less acute, but without any organic legion of the viscus.

The treatment of this affection by galvanism is sometimes very successful. The positive pole is to be placed upon the lower cervical vertebræ, the negative over the stomach pit, below any painful spot. A current of 8 mv. (20-30 El.) is to be used for 6-8 minutes daily.

Dilatation of the Stomach.

This may be consecutive to organic lesions, and then electricity has no beneficial effect. But when resulting from atony or paraly-

sis of the muscular fibres of the stomach, this mode of treatment gives better results than those obtained from any other therapeutical agent. The positive pole must be placed on the abdominal walls over the distended organ, the negative upon the third dorsal vertebra. After using in this way a current of 8-10 mv. (30 El.) for five or six minutes the poles will be placed over the greater or lesser curve of the stomach, and some interruptions made so as to excite contractions of its muscular walls. For this purpose a faradic current of medium strength may also advantageously be used; one or two interruptions only in the second are to be made. The electrodes must be placed on either side near the false ribs. The sittings to take place daily.

Nervous Vomiting.

This affection, also called essential vomiting, is characterised by the frequent bringing up of mucus or food, without the presence of any pain nor any organic lesion in the stomach. The sedative action of a descending current will prove useful; the positive pole is to be applied at the level of the lower cervical vertebræ, the negative over the stomach pit. A current of 5 mv. (12-15 El.) is to be used at first, gradually increased to 10 mv. (25-30 El.) The sittings must be repeated daily.

Enteralgia.

A descending galvanic current is to be applied, the positive pole being held over the tenth dorsal vertebra, the negative below the umbilicus. Current strength 8 mv. (20-30 El.)

Intestinal Obstruction.

The stoppage of fæcal matter in the intestinal tube may be due either to its constriction, or a dilatation of its walls.

1. *Constriction.*—When this is due, independently of any lesion, to a spasmodic contraction of the circular fibres, a galvanic current of 10-12 mv. (30 El.) is to be sent through, the positive pole being on the abdomen, the negative in the rectum. Or a faradic current with very rapid intermittences may be used in the same way.

Usually it is in real cases of constriction that recourse is had to electricity, and sometimes this mode of treatment may save a patient otherwise doomed to certain death. In such cases, we begin by faradising the intestines during 3-4 minutes with a current of 2-3 intermittences a second, but very powerful, the electrodes being placed on the abdomen and in the rectum respectively. Secondly, the interrupted galvanic current is to be applied in the same way. Lastly, a powerful continuous current is applied to the walls of the abdomen. Two or three sittings daily.

2. *Dilatation.*—When the muscular elements of the intestines are paralysed, the tube looses its tonicity and becomes distended with the accumulation of fæcal matter. The peristaltic movements are abolished, and symptoms of persistent constipation appear. Electricity is of the highest value in restoring their tonicity to the

muscular fibres. The treatment must be the same, but much milder than that just described. The peristaltic movements become more active, and often, after a few sittings, the normal tonicity of the organ has returned.

DISEASES OF THE GENITO-URINARY ORGANS.

Paralysis of the Bladder.

Faradism and galvanism have both been used in the treatment of this disease; but the latter has given the best results. There are two modes of application:—

1. If catheterism is not painful, one of the poles (negative) is introduced into the bladder by means of a flexible wire in a gum catheter, whilst the positive is held over the spine. Current strength, 8 mv. (20-30 El.) duration, 5 minutes. Water is to be injected into the bladder so as to prevent any electrolytical action upon any point of mucous membrane, and to expose the whole surface of the organ to the electrical action.

2. When catheterism is painful, it is enough to apply the positive pole to the lower dorsal vertebræ, and the negative above the pubes. Current strength 10-12 mv. (30-40 El.). Duration, 8 minutes. The positive is during the latter part of the sitting to be placed upon the peritoneum, whilst the negative is left in place. When faradisation is resorted to, one of the poles must always be placed in the bladder.

Incontinence of Urine in Children.

Galvanisation of the lower part of the spine almost invariably brings about a radical cure. A descending current from 5-12 mv. (15-40 El.) according to the strength and sensitiveness of the patient is to be used daily for 10 minutes. The advantage of this method is very apparent in children where catheterism is to be avoided.

There is less indication for faradism, but it may be applied also where there is weakness of the muscles of the bladder. One of the poles is then placed on the perineum, the other over the pubes, and a medium current is sent through for only 2 or 3 minutes. When galvanism is used, the electrodes may be applied to the same spots for a few minutes, at the beginning of each sitting.

Vesical and Urethral Spasms.

Here the influence of galvanism is most remarkable, and there are few diseases in which their usefulness is so marked. We have observed several cases in which the patients complained of a sensation of weight in the bladder, of frequent desire to make water, of tenesmus, painful erections, and where all these symptoms have been removed almost completely after a very few sittings. A descending current of 10-15 mv. (30-50 el.) is applied for 8-10 minutes along the spinal cord; and during a few minutes a current of 8 mv. (15-30 El.) may be sent from the perineum to the pubes. Of

course where these symptoms are the result of organic lesions no durable cure can be effected; but galvanism is of the highest value to the surgeon, as it calms the spasms for a while, and allows a more or less considerable distention of the bladder.

Spermatorrhea.

Galvanism has often given us very good results. We first apply a descending current to the spine; then for a few minutes we place the positive pole upon the perineum, and the negative upon the sacrum. Current strengths and duration, as above. When a rapid improvement is not thus obtained, a small electrical sound is to be introduced into the urethra, and brought in the neighbourhood of the vesiculæ seminales. It forms the positive pole. Current of 6-8 mv. (12-18 El.) for 2 minutes.

Hypertrophy of the Prostate.

In the pure hypertrophy, electricity has not given us any very satisfactory results. But when the sequela of an acute prostatitis, or of a congestive process, the currents can bring back the organ to its natural size. Faradisation must be used first, one of the poles being applied per rectum; a moderate current to be used for 2 or 3 minutes. A little later, or at once if any spasms exist, galvanism must be used. The negative pole is placed over the pubes, the positive on the perineum or in the rectum as before. Current strength, 8 mv. (20-30 El.) Duration, 5-6 minutes.

Amenorrhea. Dysmenorrhea.

Galvanism has a decided action upon the menstrual flow. In numerous cases where we treated other diseases in women, we have been struck by the increase in the amount of blood lost. In a chlorotic girl who had not menstruated for 5 months, the menser reappeared after 6 sittings. It is necessary not only to act locally by sending a current of 10-12 mv. (30-40 El.) from the lumbar region to the abdominal walls, but also, and chiefly, to galvanise the vaso-motor centres at the upper part of the cord.

Uterine Flexions and Congestions.

Several physicians have treated these affections electrically. Faradism is used, one of the electrodes being placed above the pubes, the other in the anterior or posterior cul-de-sac, according as we have to do with ante- or retro-flexion.

This mode of application may restore their tonicity to the relaxed fibres, and correct even old flexions.

In circulatory disturbances, and congestive states of the uterus, galvanism may be of the highest use; but we never had any satisfactory results in true flexions.

Uterine Atony in Parturition.

Electricity has been used in cases where ergot is usually given to cause or increase the contractions of the uterus.

The electrodes, with a moderate faradic current, are placed upon either side of the lumbar region, or better, the one on the last lumbar vertebra, the other a little below the umbilicus. This application of the current is held to be much preferable to the use of ergot; it produces the contractions instantaneously, whilst ergot takes some time to act; these contractions are more normal and vigorous, and of definite duration, whilst those produced by ergot are less so, and sometimes permanent, so as to endanger the life of the foetus. Electricity may be used conjointly with other means; or when weakness, vomiting, etc. prevent the absorption of internal remedies.

The currents have also been used for producing premature labour. But here it is desirable previously to dilate the os with sponge-tents or other means. The contractions then are immediately produced by faradisation, and at once assume a normal course.

DISEASE OF THE HEART AND RESPIRATORY ORGANS.

Nervous Palpitations.

These are most frequently symptomatic of chlorosis, and their treatment is that of the disease itself. If however very violent they may be easily diminished by the galvanic current.

For this purpose a weak descending current of 6 mv. (10-15 el.) is applied to the pneumogastric, the positive pole being on the back of the neck, the negative on the præcordial region. Each sitting to last 3-5 minutes only. After the first the patient usually feels a marked improvement, and five or six sittings are usually sufficient to obtain a considerable diminution of the symptoms.

Organic Diseases of The Heart.

Some physicians have used electricity in organic diseases of the heart. Here, evidently, a cure can never be effected; but the patient feels considerably relieved, respiration becomes less frequent, and dyspnœic, and the action of the heart more regular.

Faradisation is to be applied over the precordial region. If only two interruptions a second be made, it may also be applied to the pneumogastric nerve. We have performed this operation in several cases without ever meeting with the slightest accident. When galvanism is used, a moderate current is to be used daily. We know several patients suffering from heart disease who never travel without taking with them a galvanic battery. Whenever they have an attack, they derive much benefit from an application.

Asphyxia and Syncope.

The methods of electrisation in these cases vary according to the kind of current used.

Faradism.—The best way is to faradise the phrenic nerve in order to produce artificial respiration. The current must be strong but bearable. The two electrodes are placed on the sides of the

neck at its lower part, between the anterior scalenus, and the external border of the sterno-mastoid. The current must be allowed to pass for 2 seconds at a time. The expiration is facilitated by proper pressure upon the thorax. But this process is very dangerous in the hands of persons not familiar with the method.

Another way is to faradise the skin over the præcordial region, so as to act reflexly upon the centres of innervation of the heart and respiratory organs. A fine metallic conductor is placed over the left nipple, whilst the other is placed over the region of the apex. The current must have rapid intermittences.

The same process may be used in cases of apparent death of new-born children; and it is a good plan, between the intervals of faradisation, to place them in a hot bath.

Galvanism.—The numerous experiments we have performed, and elsewhere reported, show that the galvanic current is preferable for the restoration of the respiratory and cardiac movement in cases of asphyxia by chloroform and other anæsthetics, and especially in cases of syncope following abundant losses of blood. These currents have the further advantage of offering no danger in their use; and never cause any arrest of the heart's action, as is frequently the case in the unskilful application of even a moderate faradic current. The method consists in galvanising the whole body by putting the positive pole in the rectum, and the negative in the mouth. A current of 10 mv. (20-30 El.) is to be sent through until respiration be completely re-established. If a stronger current be used, the poles may be placed upon the neck and præcordial region. The electrisation is not to be suspended until respiration is quite normal, otherwise the respiratory movements gradually become weaker again, and disappear completely and for ever.

AFFECTIONS OF THE EYE.

Ptosis of the Upper Eyelid.

Usually this paralysis is consecutive to a disease of the third pair and is accompanied with paralysis of some of the eye muscles, or with mydriasis. Galvanism is here far to be preferred to faradism; the more so that induced currents frequently have gravely injured the optic nerve. The positive pole is to be placed upon the eyelid, the negative upon the superior cervical ganglion, below the mastoid process. Current of 6-8 mv. (10-12 El.) Interruptions must be avoided.

Paralysis of the Muscles of the Eye.—Diplopia.—Paresis of Accommodation.—Mydriasis.

These diseases being due to a lesion of the third pair, are to be treated as just described under ptosis.

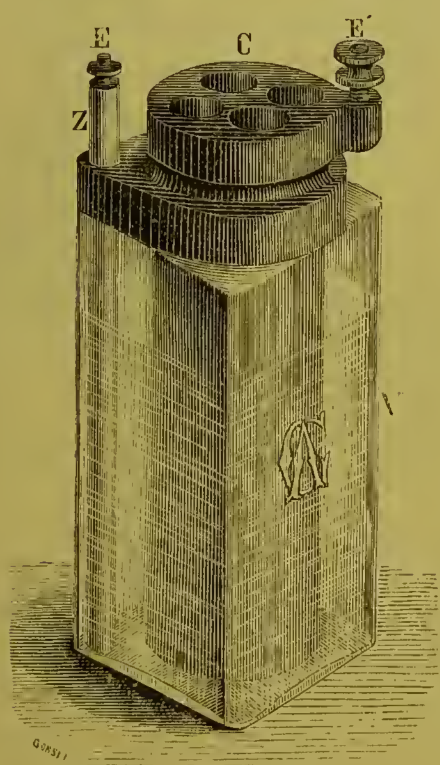
Opacities of the Vitreous Body.—Occlusion of the Pupil.—Synechiæ.

Galvanism has a very beneficial effect upon the reabsorption of these opacities, as well as upon synechiæ following iritis, and which produce a more or less complete occlusion of the pupillar aperture. This result may be obtained by influencing the encephalic circulation; either the positive pole may be placed upon the eye, and the negative upon the superior cervical ganglion; or both poles over the cervical ganglion on either side. A current of 6-8 mv. (10-12 El.) to be used from 5-8 minutes.

Atrophy of the Optic Nerve.

If this affection presents the symptoms of *grey* atrophy and is then only a symptom of a more widely-diffused spinal disease, such as locomotor ataxy, an ascending current is to be applied to the cord as described previously, paying particular attention to the galvanization of the cervical spine. If on the other hand the atrophy is *white* and is due to a lesion of the nutrition, or is consecutive to a neuro-retinitis, the encephalic circulation must be acted upon, and the cervical ganglia influenced as under the preceding head. In most cases the progressive development of the disease will be arrested, and in a good many cases a very marked improvement, if not a cure, will be obtained.

Fig. 93.



Gaiffe's peroxide of manganese element, see page 142.

FIG. 94.

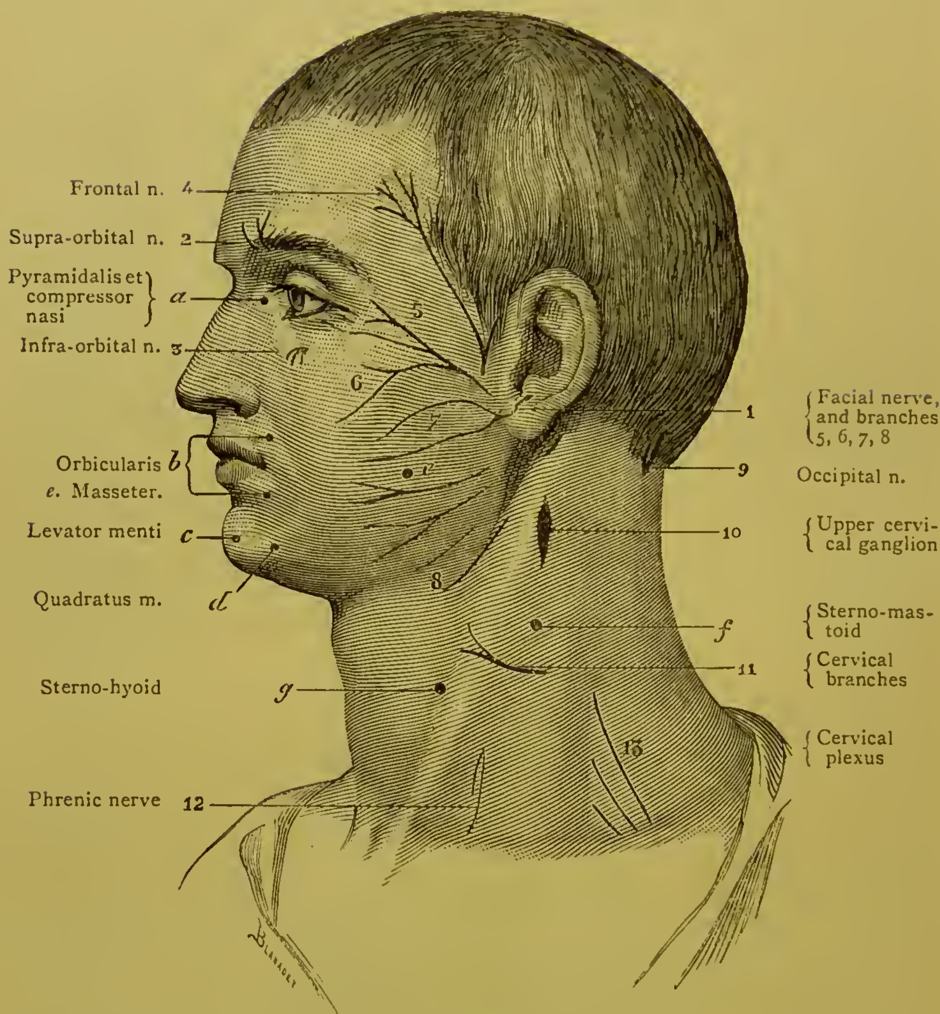

Frontal n. 4
Supra-orbital n. 2
Pyramidalis et compressor nasi a
Infra-orbital n. 3
Orbicularis b
e. Masseter.
Levator menti c
Quadratus m. d
Sterno-hyoid g
Phrenic nerve 12
1 Facial nerve, and branches 5, 6, 7, 8
9 Occipital n.
10 Upper cervical ganglion
f Sterno-mastoid
11 Cervical branches
13 Cervical plexus

FIG. 95.


Supinator longus
a
Extensor radialis longior
b
Extensor radialis brevior
c
Extensor communis digitorum
d
Extensor indicis
e
Abductor pollicis longus
f
Extensor brevis pollicis
g
Abductor indicis
h
1
Ulnar nerve
Extensor carpi ulnaris
Extensor minimi digiti
Extensor indicis
Extensor longus pollicis
Abductor minimi digiti
i
Dorsal interossei

Fig. 96.

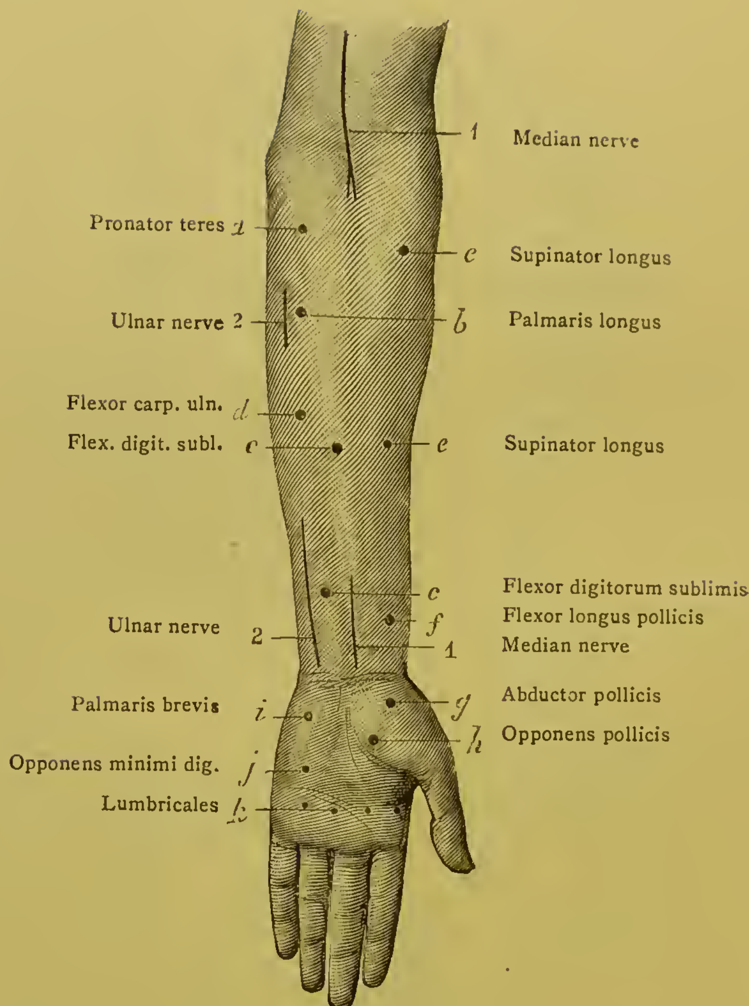

1 Median nerve
Pronator teres a
e Supinator longus
Ulnar nerve 2
b Palmaris longus
Flexor carp. uln. d
Flex. digit. subl. c
e Supinator longus
c Flexor digitorum sublimis
f Flexor longus pollicis
1 Median nerve
Ulnar nerve 2
Palmaris brevis i
g Abductor pollicis
h Opponens pollicis
Opponens minimi dig. j
Lumbricales k

FIG. 97.

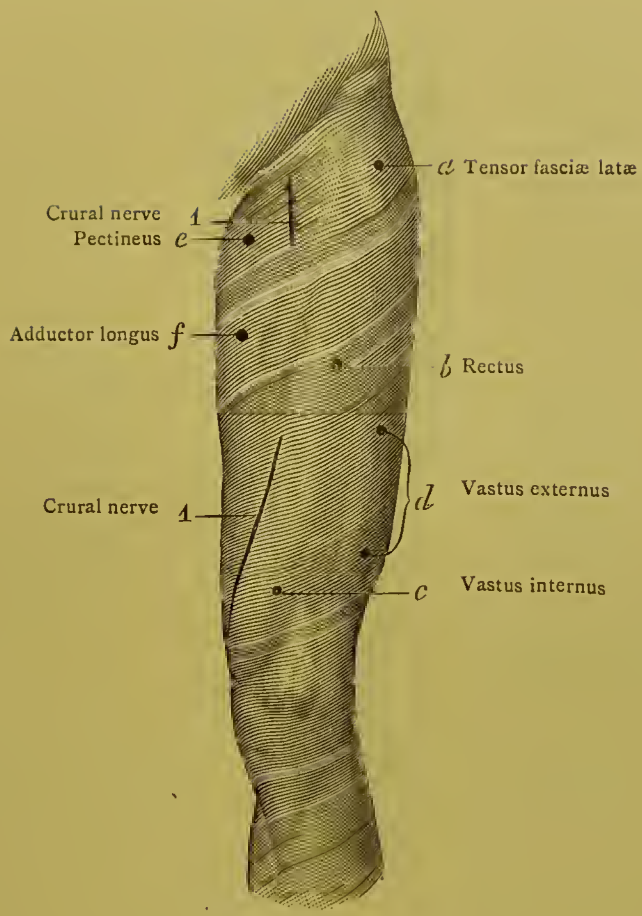

a Tensor fasciæ latæ
Crural nerve 1
Pectineus e
Adductor longus f
b Rectus
d Vastus externus
Crural nerve 1
c Vastus internus

Fig. 98.

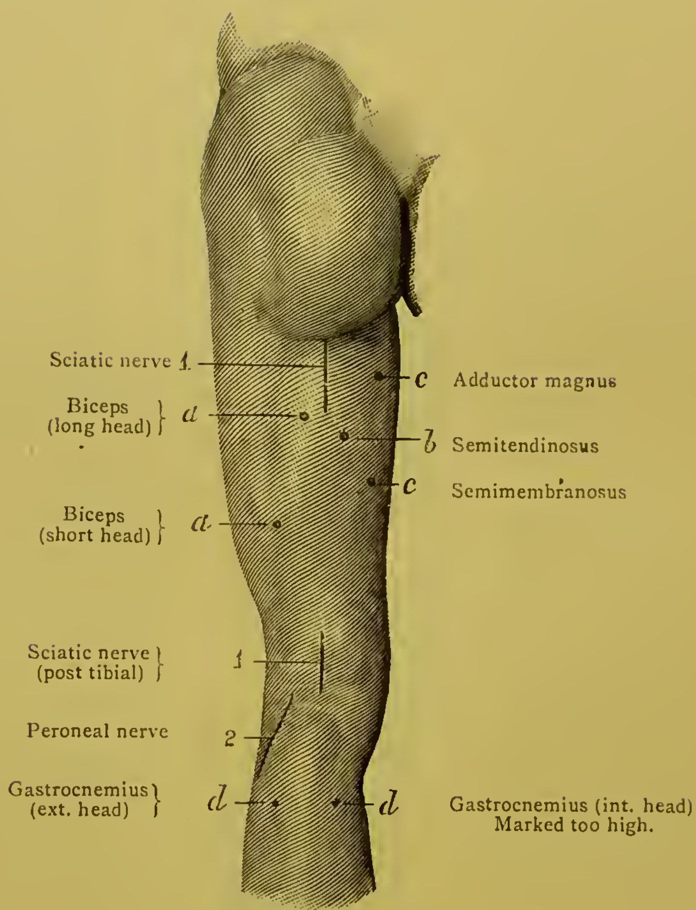
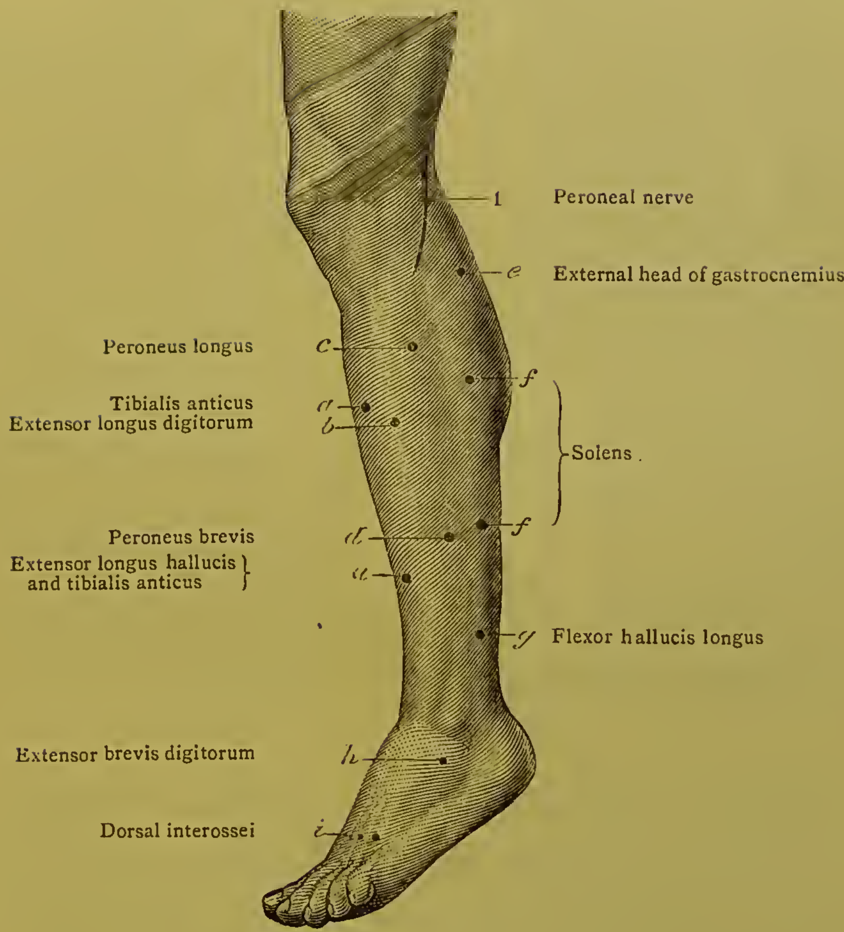

Sciatic nerve 1
Biceps (long head) a
Biceps (short head) a
Sciatic nerve (post tibial) 1
Peroneal nerve 2
Gastrocnemius (ext. head) d
c Adductor magnus
b Semitendinosus
c Semimembranosus
d Gastrocnemius (int. head) Marked too high.

FIG. 99.


Peroneal nerve
External head of gastrocnemius
Peroneus longus
Tibialis anticus
Extensor longus digitorum
Solens .
Peroneus brevis
Extensor longus hallucis and tibialis anticus
Flexor hallucis longus
Extensor brevis digitorum
Dorsal interossei

APPENDIX.

Gaiffe's Peroxide of Manganese Element.

The objections to the Leclanché as usually constructed are mainly the following:—It cannot be recharged except by the patentees. It is liable to get out of order owing to the creeping up or incrustation of its salts, and the evaporation of the water it contains.

These drawbacks appear to be completely obviated in Gaiffe's new element, fig. 93. It consists of the usual glass cell, V, which contains, as exciting liquid, a 20 per cent solution of chloride of zinc instead of chloride of ammonia. The carbon, C, is in the shape of a cylinder, into which one or more holes are bored along its whole length; into these holes granular peroxide of manganese is packed. The zinc, Z, and the carbon, carry binding screws for connection.

In order to recharge this element, all we have to do is to pour out the liquid, and shake out the manganese, and replace them—an operation which obviously is neither long nor difficult. There is no creeping up of salts, and the oxide of zinc formed does not adhere to the zinc rod, but falls to the bottom in a pulverulent state.

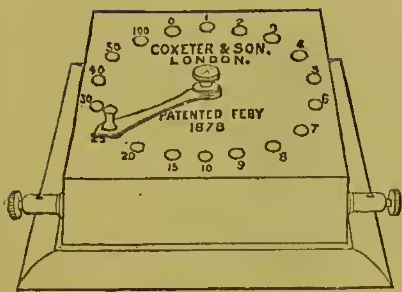
The affinity of the chloride for water considerably diminishes the amount of evaporation. The electromotive force, and I may add the cost, of this much improved element, are the same as those of the usual Leclanché.

Coxeter's Peroxide of Manganese Battery, and Rheostat.

Reference has already been made to Coxeter's element in which platinum replaces the carbon of the Leclanché. Experiments seem to show that this cell is a decided improvement both as to constancy and durability, otherwise it closely resembles the usual Leclanché both as regards size and external aspect. It consists of a vulcanite cell and the connections are made by soldering. Its cost is not more elevated than that of its prototype; altogether it deserves extensive trial.

The new rheostat shown in figure 100 consists of a rectangular box carrying a number of studs taken one by one by means of a switch, as in the ordinary dial collector. Each stud is numbered so as to indicate the number of ohms (in thousands) included in the circuit. The resisting medium is a compound of a metallic powder

FIG. 100.



with a non-conducting substance, as described at page 17. The size of the rheostat here figured is 3 inches square by 1 inch in height, and it weighs but a few ounces. Its price is low. Of course it is not intended as an accurate measuring instrument, but simply designed to introduce such resistances, approximately estimated in thousands of ohms, as to regulate the current strength for medial purposes.

In the appended figure (fig. 101) a battery is represented consisting of 30 Coxeter elements. They are taken by tens by means of binding screws and wires as depicted, the finer regulation of current strength is effected by means of a rheostat (not shown, but which may be inserted in the handle of one of the electrodes). On the lid is fixed a vertical galvanometer, and on the element board a commutator to the extremities of which are screws for the attachment of the rheophores. Size of 30 celled battery: $9+6\frac{1}{2}+6$ inches. Weight; $11\frac{1}{2}$ pounds.

FIG. 101.

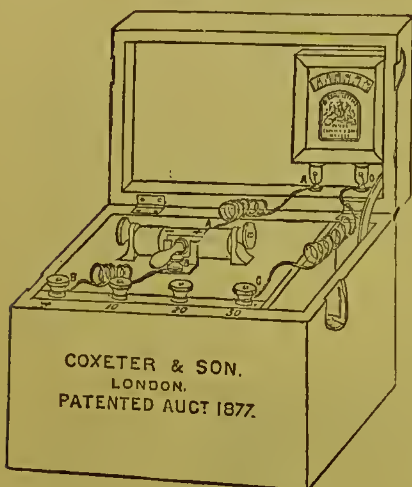
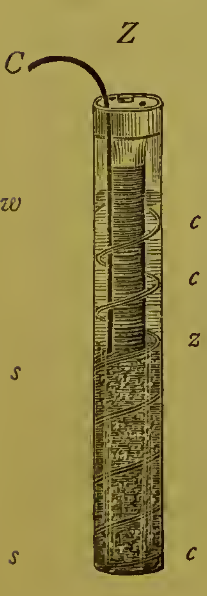


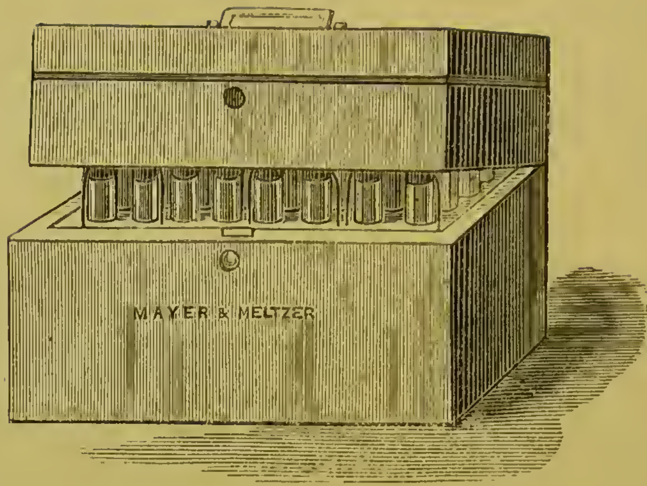
FIG. 102.



MAYER AND MELTZER'S SULPHATE OF COPPER BATTERY.

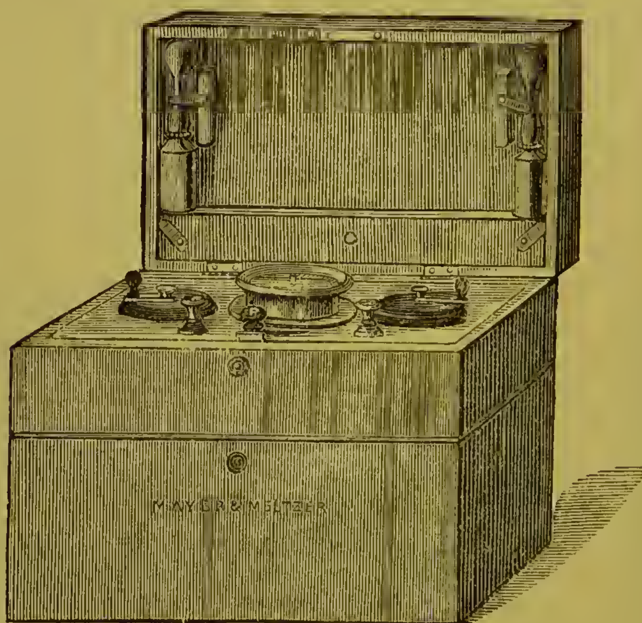
The new element fig. 102, is made of an ordinary test-tube. The positive pole consists of an insulated wire C plunging to the bottom where it is connected with a spiral of copper wire c; c, c. The negative pole, Z, is formed of a cylinder of zinc, z, enclosed in a bag of strong calico. The lower half of the tube is filled with sulphate of copper and water poured in up to w. The advantages claimed for this arrangement are that when at rest, there is but little reduction of the sulphate of copper; that the element is exceedingly portable; and that it has all the characteristic constancy of the ordinary Daniell.

FIG. 103.



The cells are arranged in trays of five each, which can be lifted out from the box for inspection, the connection being made by means of springs. The case opens in two places so as to give access to the cells, fig. 103, and to the element-board, fig. 104. The latter carries a galvanometer, a commutator, P, an interruptor, and a dial collector.

FIG. 104.

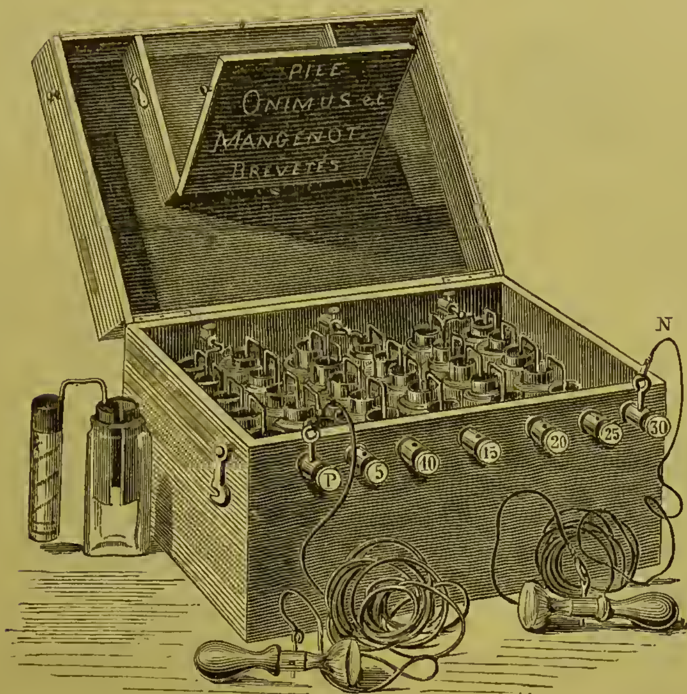


This battery is exceedingly compact and portable, measuring only 12 × 7 × 6 inches, and weighing only 13 pounds for 50 elements.

Sulphate of Copper Battery of Dr. Onimus and M. Mangenot.

This battery (fig. 165) consists of elements one of which is represented in the figure. A glass cell contains in its upper part a cylinder

Fig. 105.



of zinc. Within this cylinder is a porous cell of parchment containing a spiral of copper wire, and partially filled with bits of sandstone. Water is poured into both compartments so as to cover the sandstone; and a few crystals of sulphate of copper dropped into the porous cell, the quantity being regulated by the work to be done by the battery. In this way all action is avoided in the cells whilst at rest; the operation of charging is a very simple one; and the battery is not liable to get out of order, and very easily repaired when it does so. The figure represents a simple battery in which the elements are taken five at a time by means of a pin and hole collector; for practitioner's use the battery is fitted with dial collector and galvanometer.

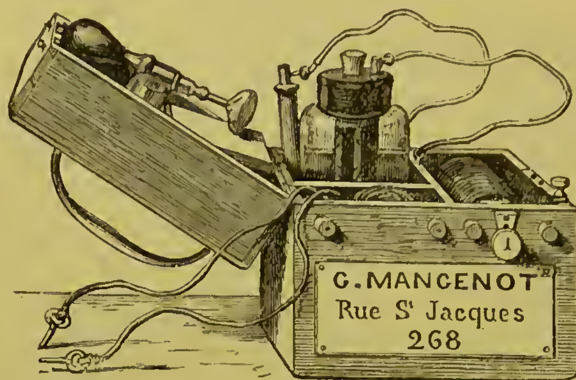
Faradic Apparatus with German Silver Coil.

The physical differences between various metals considered as conductors, are naturally followed by physiological differences in the effects produced by currents induced in coils made of these metals. Hitherto copper has been universally employed in the manufacture of medical coils. Dr. Onimus, however, prefers for some purposes coils made of metals with a higher specific resistance. Experiment shows that coils made of lead or german

silver, *cæteris paribus*, give currents which excite the muscles as powerfully as copper coils, whilst they do not produce such painful cutaneous impressions.

The appended figure (fig. 106), shows a faradic instrument with a

Fig. 106.

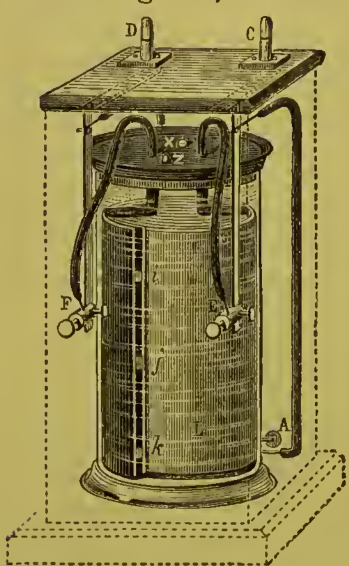


coil of german silver. The cell used is a bisulphate of mercury element, which is put in and out of action by inserting into it, or removing from it, a zinc rod. Once charged it acts for three months without care. The current is regulated by means of the draw-tube.

This apparatus measures 4 × 5 × 4½ inches; and weighs about 2 pounds.

POLARISATION CELLS AND TROUVÉ'S POLYSCOPE.

Fig. 107.



When two plates of platinum are dipped in water and attached to the poles of a battery, they become polarised, that is, the anodal plate becomes covered with bubbles of oxygen, the cathodal with bubbles of hydrogen. If now the plates are connected with the terminals of a galvanometer, it is found that a polarisation current is set up from the hydrogen through the liquid to the oxygen (*i. e.* in the opposite direction to the battery current) and that this polarisation current may last a considerable time if the plates are large enough. This property has been made use of in the construction of what are now called secondary cells. For instance in fig. 107 we have a representation of Planté's cell. It consists mainly of two plates of lead, L, rolled into spirals, one within the other, but kept from contact by means of strips of vulcanite, *i j k*, they

are connected to the polarising battery by means of two wires E F, and to two terminals, C D, which give the polarisation current. To set the battery in action, we have simply to fill the secondary cell with water containing 10 per cent. of sulphuric acid, and connect the binding screws, E F, to a battery of 4 Daniells or 2 Bunsens. After a while the cell is charged; if now a wire be attached to C D, the polarisation current will flow through it and keep it hot until the electro-motive force stored up is expended.

M. Trouvé has very ingeniously applied the polarisation cell to the production of light for medical purposes. The instrument, named electrical polyscope is illustrated in the following figures.

FIG. 108.

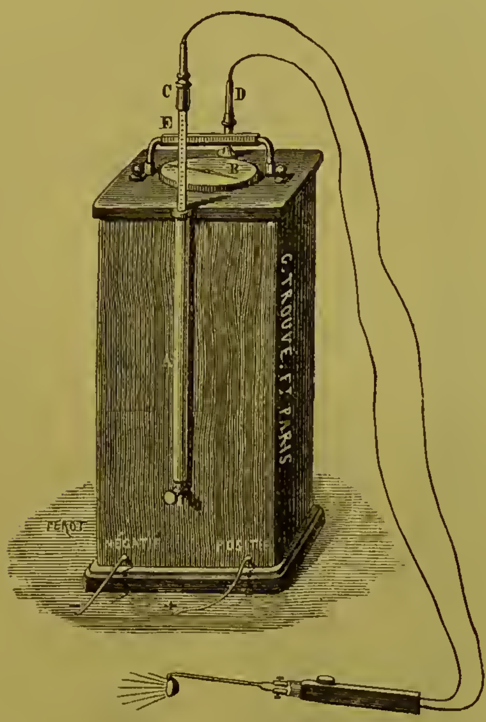


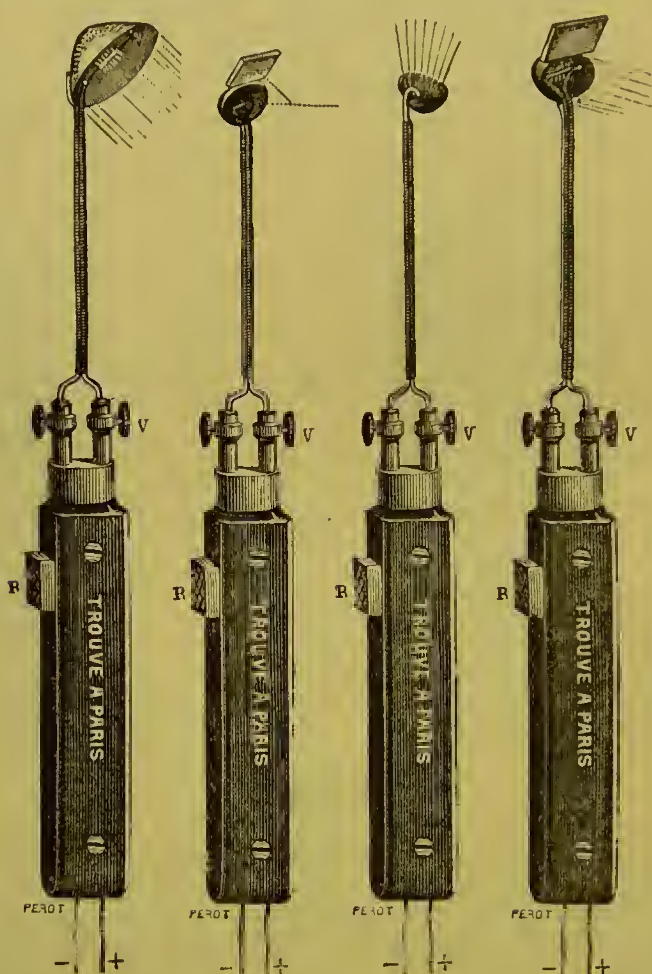
FIG. 109.

Fig. 108 represents the instrument at work. The secondary cell is contained in a rectangular case about 12 inches high, by 6½ inches in breadth and depth. It weighs 5 or 6 pounds. At the bottom are seen the points of attachment for the wires of the charging battery (+ and —). E, is the handle for carrying it.

A, is the rheostat or current regulator; B, the galvanometer; C and D, clips for fastening the rheophores conveying the current to a handle (fig. 109). This handle here carries a sliding piece R, for making and breaking the current with the finger, and screws, V, to which the various terminals for illumination or cauterisation are attached; the one here figured is in the shape of a galvano-caustic knife for minor operations. Figs. 111 and 113 represent reflectors for the larynx. Fig. 110 is adapted for the examination

of the mouth and teeth which appear translucent. The same is said to be the case with the stomach when this powerful illuminator is introduced into it by means of an œsophageal bougie. Fig. 112 represents a reflector adapted for the examination of the pharynx, nose, vagina, rectum, etc. The great advantage of it is that the source of light can be closely approximated to the part to be examined, whilst the observer is protected from its rays. There are also special illuminators for the eye and ear.

FIG. 110. FIG. 111. FIG. 112. FIG. 113.



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